POWER PLANT ENGINEERING

Established Over 30 Years

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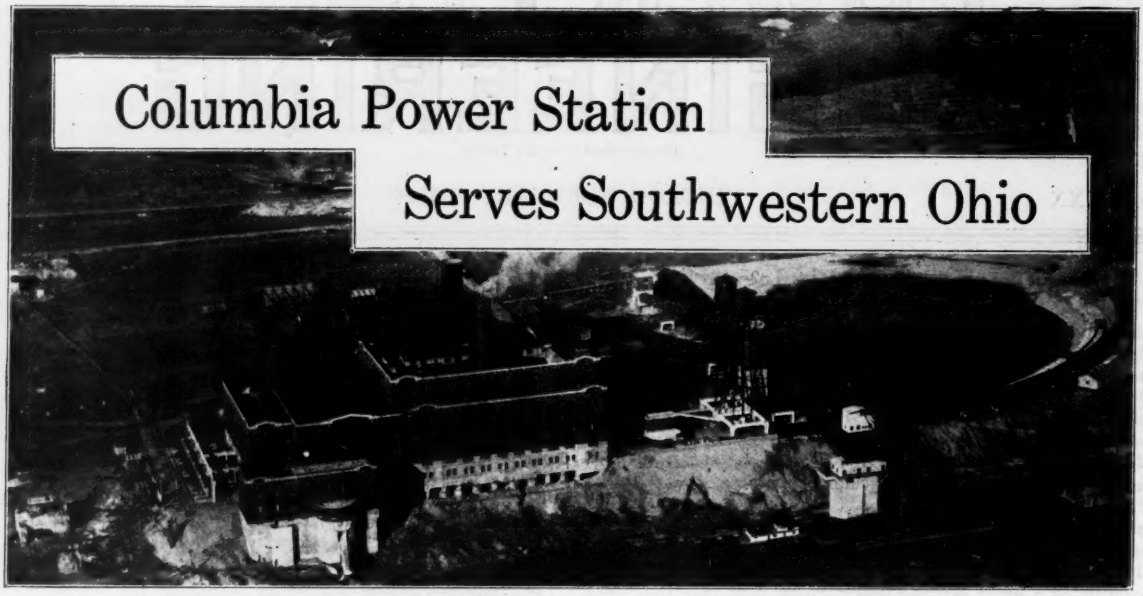
Nothing Needed but the Champagne

WE ARE beginning to take a new attitude toward the opening of large central stations, as the above illustration shows. We are beginning to treat them as public events, rather than as strictly engineering procedures, and to put them on a parity with the launching of ships, the opening of great bridges and the laying of cornerstones of great buildings. Nothing is needed in the interesting group above but a bottle of champagne for the young lady to break over one end of the turbine.

This photograph was taken on December 10, 1925, at the formal dedication of Columbia Power Station, a new base load station of the Columbia Power Co., located on the Ohio River about 20 mi. from Cincinnati, Ohio. The station is designed for an ultimate capacity of 360,000 kw. The ceremonies attending the opening were elaborate and unusually interesting. Miss Virginia Junggren, daughter of the designer of the tandem-compound 45,000-kw. turbo-generators installed in Columbia, started the first unit, as shown above.

In short, nothing was left undone to make the opening of Columbia Power Station a public occasion not only for the people of Southwestern Ohio, which the station will serve, but also for the general public. This general public, of course, is more interested in the size and cost of the undertaking and the results that will be obtained. To the engineer, however, the details of construction and equipment are of vital importance and he will find these details in the description of Columbia Power Station in this issue.

Columbia Power Station Serves Southwestern Ohio



NEW PLANT OF COLUMBIA POWER CO., ABOUT 20 MI. WEST OF CINCINNATI, USES PULVERIZED COAL, TANDEM-COMPOUND TURBINES WITH REHEAT, AIR PREHEATERS AND OTHER INTERESTING EQUIPMENT

NEAR THE CONFLUENCE of the Ohio River and the Big Miami River, about 20 mi. from Cincinnati, Ohio, the Columbia Power Co. has recently put into operation its new Columbia Power Station. This station, the first unit of which contains two 45,000-kw. tandem turbo-generators, is designed to have an ultimate capacity of eight generating units, a total of 360,000 kw. The plant, formerly known as Miami Fort Station, is designed to take the base load of the Columbia Gas & Electric Co.'s system. At the present time it is tied in with the West End station in Cincinnati and with the Miller's Ford Station at Dayton, Ohio.

General arrangement of the plant is shown in the headpiece and in Fig. 12, the layout of equipment appearing in Figs. 7, 9 and 11. The plant building itself is constructed on concrete piers, as shown in Fig. 9, the walls being of red tapestry brick with limestone trim and steel window sash. The building proper is approximately 390 ft. long and 192 ft. wide, as shown in Fig. 11, exclusive of the crib house. The plant stands on the north bank of the Ohio River, the coal handling and storage equipment being to the east of it.

MOST OF COAL TO BE RECEIVED BY RIVER

Under normal operating conditions, most of the coal burned at Columbia Station will arrive by river in steel coal barges holding 1000 t. each. To provide for emergencies, however, coal can be brought in by rail. The coal storage space has an area of about 300,000 sq. ft. and will hold 122,000 t. of coal piled 20 ft. deep and 180,000 t. piled 30 ft. deep.

Rail coal is received in hopper bottom cars, which dump into a track hopper near the north end of the conveyor. From this hopper it is fed by reciprocating feeders to a belt conveyor leading to the junction house, which forms the terminal of the north wing of the main conveyor, which takes the coal to the crusher house, shown in Fig. 11 B, and Fig. 12. Coal is dumped from the belt conveyor into a hopper in the top floor of the crusher house and from this hopper can be spouted out to the initial storage pile

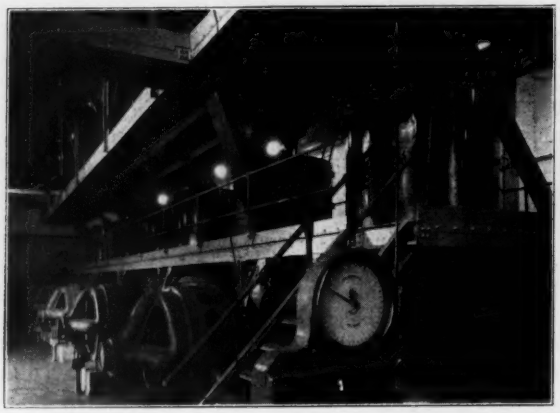


FIG. 1. SLIP RING INDUCTION MOTORS DRIVE SIX 57-IN. SCREEN TYPE MILLS

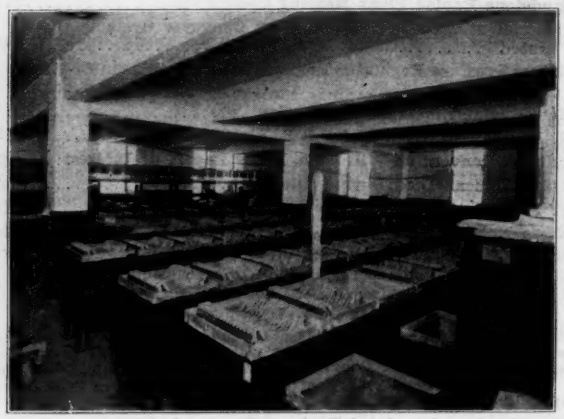


FIG. 2. STORAGE BATTERIES GIVE RESERVE EXCITATION AND D.C. STATION POWER

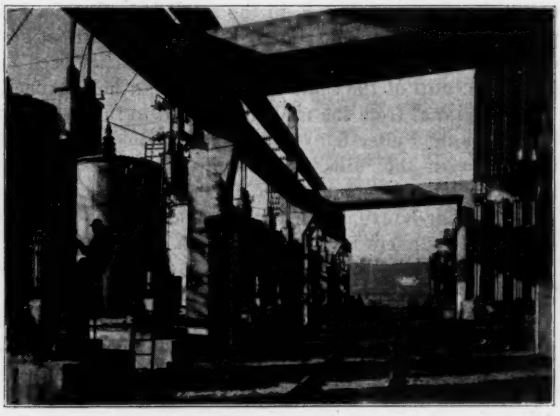


FIG. 3. 10,000 KV.A., 66,000-V. POWER TRANSFORMERS AT LEFT, STATION AUXILIARY TRANSFORMERS AT RIGHT

FIG. 5. INSTALLING TRIPLEX PULVERIZED COAL FEEDERS AND BUNKERS ON FEEDER FLOOR

or sent to the crushers directly under the hoppers. Two No. 60 American Ring Crushers are installed here, each driven by a direct-connected, 100-hp. squirrel cage motor and each of 250 t. per hr. capacity. From these crushers the coal is put on the west wing of the belt conveyor leading from the crusher house to the northeast corner of the station building, as shown in the headpiece and in Figs. 10 B and 12.

Coal arriving by water is handled by the unloading tower shown in Fig. 10 F. and also at the right of both Fig. 12 and the headpiece. The grab-bucket has a capacity of 4 t. and the whole equipment is designed for a capacity of 375 t. per hr. At the top of the tower is a house containing the hoist control and the bucket hoisting motors with Ward-Leonard variable voltage control, the contactor panels and electrical devices for the control being mounted beside the motors. In this house are also located two 75-cu. ft. per min. motor-driven air compressors, which supply compressed air for all clutches and brakes on the hoisting equipment. All the controls for this equipment are centered in the operator's cab, a small house located just below the level of the bridge. The bucket deposits coal in a 100-t. receiving hopper on the lower level; from this hopper the coal is dropped onto the south wing of the belt conveyor.

Belt Conveyors Handle 500 t. of Coal an Hour

Belt conveyors travel at a speed of 170 ft. per min. and have a capacity of 500 t. an hour. Coal passing on the belt conveyor from the barge unloading tower goes to the hopper in the crusher house, as mentioned above, from which it can be discharged to storage or crushed and sent to storage or to the belt conveyor leading into the plant, in the same manner as rail coal. A Beaumont 4-t. drag scraper is used to distribute the coal in the storage space or to reclaim it for use.

At the top level of the preparation room are two 500-t. raw coal bunkers. Coal passes from these bunkers to the

FIG. 4. HIGH AND LOW PRESSURE TURBINE CYLINDERS, MAIN GENERATOR AND EXCITER AND AUXILIARY GENERATOR ARE ON ONE SHAFT

FIG. 6. 66,000-V. FEEDER CONTROL PANEL AT HARTWELL TERMINAL SUBSTATION

drag conveyor shown in Fig. 9, which takes it to the two indirect pulverized coal fired rotary dryers. These are 6 ft. in diameter and 50 ft. long, with a capacity of 30 t. each when removing 3 per cent of moisture. Hot gases from the dryer furnace pass around and through the dryer to an exhaust fan which forces the gases through a cyclone separator and air washer to the atmosphere. From the dryers, the coal is carried on another drag conveyor, shown just below the dryers in Fig. 9, to the small bins that feed the pulverizing mills. These consist of six 57-in. vertical gear-driven screen type mills of 8 t. an hour capacity each and one 70-in. mill of the same type of 20-t. an hour capacity. Pulverized coal from the mills is pumped to the weigh bins by three 6-in. Fuller-Kinyon pumps, installed on the main floor between the mills. The weigh bins, as shown, are large conical bins mounted on Fairbanks scales. The two 10-in. Fuller-Kinyon pumps that pump the pulverized coal to the bunkers in the boiler room take the coal from these weigh bins, which are arranged so that one bin can be weighed and coal pumped independent of the other.

Transport lines for the pulverized coal lead from the pumps up to the coal bunker floor in the boiler house. Two 8-in. pipe lines are used for transport, one from each Fuller-Kinyon pump. These lines are equipped with the standard type of Fuller-Lehigh two-way electro-pneumatically controlled valves for controlling the flow of pulverized coal to the various boiler bunkers. Bin level indicators are supplied on these bunkers which indicate by means of lights on a control board when the bin is full. Details of burners and feeders will be given after describing the boilers.

Eight Boilers Are Now Installed

Six standard boilers and two reheat boilers are installed. Figure 10 G shows a standard boiler under erection with the economizer in place behind it. These boilers are of the cross-drum sectional water tube type, designed for 650 lb.

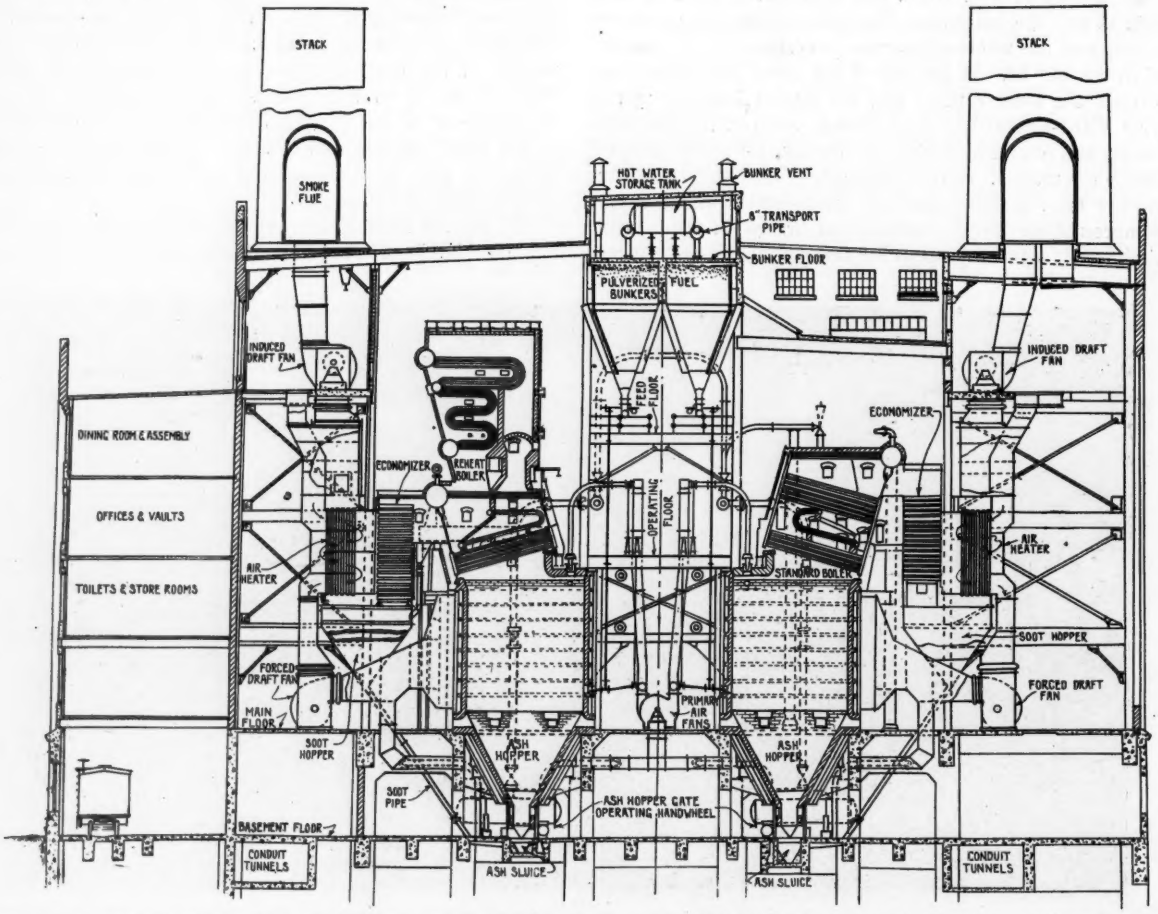


FIG. 7. AIR-COOLED FURNACES ARE EQUIPPED WITH BOTH VERTICAL AND HORIZONTAL BURNERS, PRIMARY AIR BEING USED TO COOL ASH PIT

pressure, with heating surface of 15,110 sq. ft. each. Superheaters of the interdeck type are mounted, as shown in Fig. 7, between the tube decks of the standard boilers. Five of these superheaters have 2760 sq. ft. of superheating surface each; the sixth one has 3184 sq. ft. and is equipped with a sliding damper to regulate the superheat.

Two reheat boilers, each with water heating surface of 6066 sq. ft. are installed, with primary superheaters of 1409.8 sq. ft. installed but designed for a total of 1878.5 sq. ft. if necessary. The interstage superheater of each boiler, or reheat section, as it is often called, has a heating surface of 17,612 sq. ft.

Immediately behind each boiler is a 7300-sq. ft. wrought steel counter flow economizer, flue gas from the boilers passing down through this, making a 180-deg. turn and then passing up to a 9888.5 sq. ft. tubular type air preheater. From the air preheaters the flue gas is drawn by the induced draft fans, which will be described later.

Tubes Are Cleaned with Compressed Air

Among the interesting features of the above described boiler installation is the provision for blowing tubes by compressed air, in order to eliminate the use of high-pressure steam for this purpose and at the same time to keep the heat balance of the station constant. Slight changes in the nozzles have been made to adapt the soot cleaners to air instead of steam, but otherwise the cleaning is done in the same way. It has not been found necessary to heat the air, which is taken at about 100 lb. pressure from the air storage tanks.

Another interesting item of boiler equipment is the high pressure plate type water column with which each

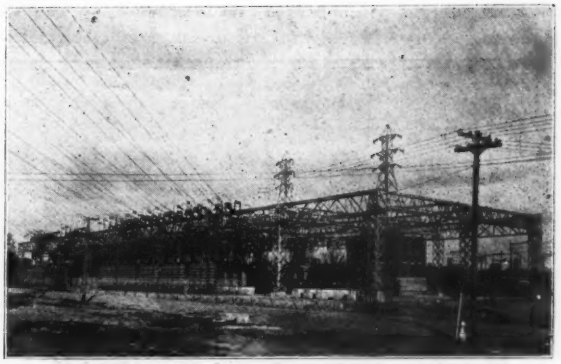


FIG. 8. POWER FROM COLUMBIA IS SENT 20 MI. TO THIS 66,000-V. OUTDOOR SUBSTATION AT HARTWELL

boiler was equipped by the manufacturer. These water columns are illuminated from the rear in such a way that the meniscus of the water level in the column is shown as an exceedingly bright spot to the operators at the control boards. Automatic control of feed water level is maintained by S-C feed water regulators; these are practically the only automatic regulating apparatus used on the boilers.

In Figs. 7, 9 and 11 is shown the general arrangement of the pulverized coal feeders, induced and forced draft fans. The coal is pumped from the weigh bins into small steel bunkers in front of each boiler. These bunkers are in groups of four, as shown in Fig. 9, each group holding about 75 t. of pulverized fuel.

There are 5 triplex feeders for each boiler, the two

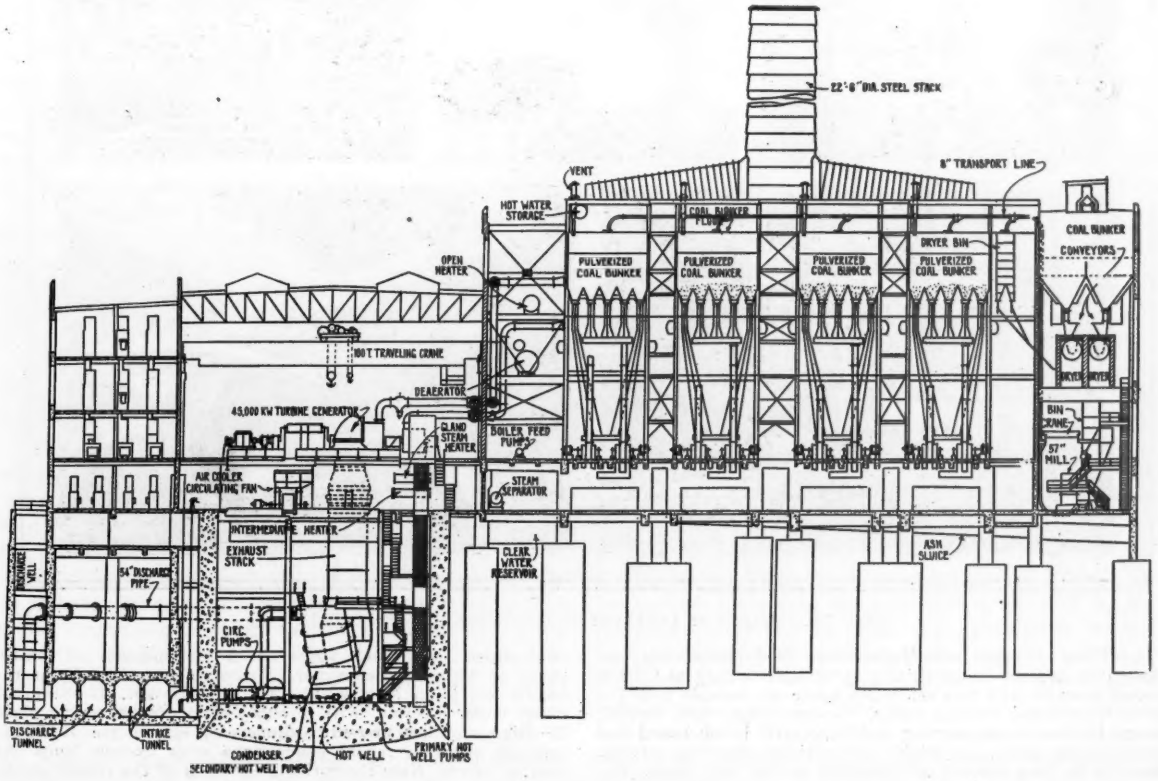


FIG. 9. LONGITUDINAL SECTION SHOWS CONDENSER WELL, ASH SLUICE, COAL FEEDER PIPING AND COAL PREPARATION PLANT

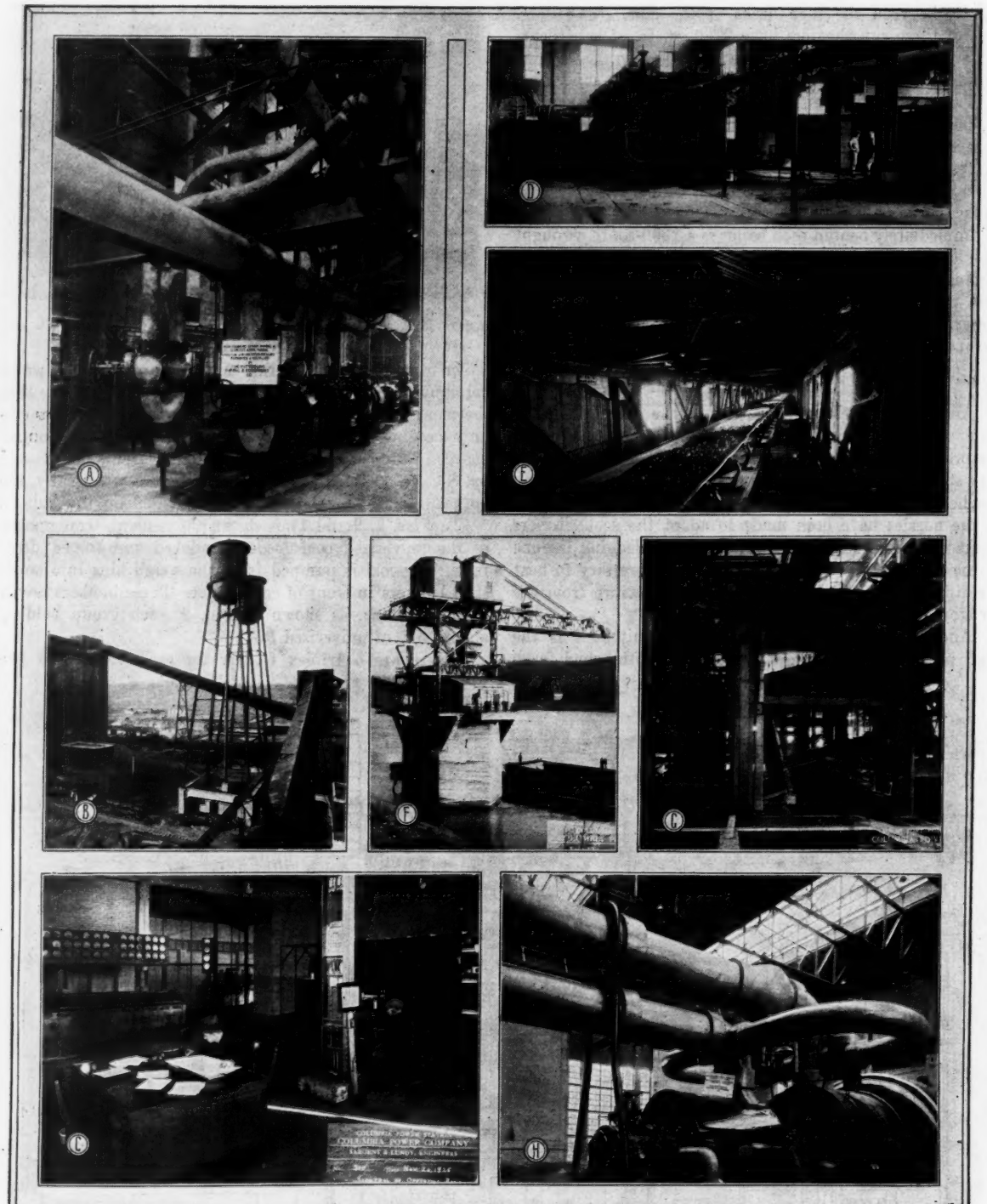


FIG. 10. POINTS OF INTEREST AT COLUMBIA POWER STATION

A—Three six-stage centrifugal boiler feed pumps, one turbine-driven and two motor-driven, serve each battery of boilers. B—Ash storage tank and ash pump house are outside near the two service water storage tanks. C—Operating room, looking toward turbine room, showing turbine control bench board and synchronizing panel. D—Eight motor-driven traveling screens, about 86 ft. long overall, are installed in the crib house. E—Coal passes from track hopper or barge unloader to crusher house on 42-in. belt conveyor. F—Barge unloading tower can handle 375 t. an hour with a 4-t. grab bucket. G—Standard boiler under erection, with wrought steel economizer in place. H—High and low pressure cylinders of one of the 45,000-kw. turbines, showing reheat connections with by-pass leads and control valves. Note the spring suspension of the reheat piping.

outside feeders supplying coal to 6 horizontal flare type burners in the front wall of the furnace near the bottom. The three inside feeders supply 9 vertical flare type burners installed in the regular way in the top of the furnace. This arrangement of burners is entirely new and is designed to produce turbulent action of the pulverized coal flames when operating the station at high ratings. For the lower ratings, only the vertical burners will be used.

Pulverized coal feeders are driven by d.c. motors, one motor to a group of three feeders, the individual feeders being connected to it by solenoid operated clutches controlled from boiler control boards on the operating floor.

Arrangement of feeders and primary air fans is somewhat different from the usual layout, as shown in the drawings. Motor-driven primary air fans, located on the main boiler room floor, take air from the air cooled ash pit and force it into headers, one in front of the six horizontal burners, and one a few feet above the level of the vertical burners, as shown in Fig. 9. Pipes carrying pulverized coal from the feeders are connected with the primary air supply just in front of the headers, the mixture going thence to the burners in the regular way.

Construction of the boiler furnaces is shown in detail in Fig. 7. Each furnace has a volume of 12,568 cu. ft. above the ash pit and 14,368 cu. ft. including the ash pit. The side walls are of the Detrick sectional supported type and are of tile supported on iron hangers with an air cooling space properly baffled, with dampers in the rear wall to control air admission and prevent chimney action. Secondary combustion air enters the hollow walls through these dampers, passes around and into the furnace through suitable ports in the front wall.

Primary Air Cools Ash Pit

Construction of the ash pit is as shown in Fig 7. This ash pit is nothing more than an extension of the furnace, built in the form of a hopper with hollow walls through which primary combustion air is taken, cooling the walls and preheating the air. The hopper terminates in a small well with an ash gate at its bottom from which the ash is dropped directly into a sluiceway, which washes it out of the plant. Sluicing water is supplied mostly by drains from the oil coolers and other miscellaneous equipment about the plant. Ash grinders are provided so that the ash can be ground before dropping into the sluiceway. The latter leads to a pit east of the plant, shown near the water tanks at the left of Fig. 10B. It is 40 ft. in diameter and 30 ft. deep and the building over one half of it contains an 8-in. single stage 1700-g.p.m. American Manganese Steel Co. ash disposal pump. It pumps the ash for filling purposes about the yard.

One of the standard boilers of No. 2 battery is now being equipped with a cylindrical furnace, in which the coal burners will be set at an angle in the sides so that their flames will enter tangent to an imaginary 10-ft. circle in the furnace and thus produce a turbulent action.

It will be noted also that a large hopper collects the ash and soot from the air preheater and economizer, a pipe leading down from this to the ash sluice beneath the boilers.

Air for combustion, taken through a duct from the induced draft fan room as shown, is brought down through the air preheaters to the forced draft fans. Each boiler has one double inlet forced draft fan direct connected to two variable speed Allis-Chalmers slip ring induction motors, one on either end of the fan shaft. One motor develops 60 hp. at 600 r.p.m., the other 125 hp. at 750 r.p.m., the change-over from one to the other for variations in boiler load being made by remote controls on the boiler panel. The armature of one motor is driven idle by the other motor that is driving the fan.

Air from the forced draft fans passes through a duct to the rear wall of the boiler, where it enters the hollow wall described above. Some of it, however, passes through the branch connection to the ash pit hollow walls and thence to the primary air fans on the main floor.

Induced draft fans, located above the boilers, as shown in Fig. 7, are of the same type as the forced draft fans, with the same size and type motors direct connected for duplex drive and remote control from the boiler panels. These fans draw the flue gas to the steel brick-lined stacks; both of these are 175 ft. high above the boiler room floor.

Boiler feed water is pumped to the boilers by six Cameron 6-stage centrifugal pumps, located at the west end of the boiler room on the main floor as shown in Fig. 10A. Four of these pumps have a capacity of 400 g.p.m. each against 680 lb. and are driven by 400-hp. direct connected Allis-Chalmers 3-phase, 60-cycle, 1800 r.p.m. motors. The other two pumps have a capacity of 500 g.p.m. each against 680 lb. and are driven by Terry type C. S. 340-hp. steam turbines. Mercon excess pressure regulators are installed on all these pumps.

Tandem-Compound Turbines Use Reheated Steam

Figure 4 shows one of the two 45,000-kw. turbo-generator units now installed in the turbine room. These turbines are of the tandem-compound type, with 14 stages in the high pressure and 12 stages in the low pressure cylinder. Steam pressure at the throttle is 550 to 600 lb. gage, 750 deg. total temperature, the entire volume of steam being taken from the turbine after passing through the high pressure cylinder, reheated at 120 lb. gage to 725 deg. and returned to the low pressure cylinder at 110 lb. gage and 725 deg.

Main generators are rated at 45,000 kw. each at 0.9 power factor, or 48,000 kv.a. They operate at 1800 r.p.m. and generate 60-cycle, 3 phase power at 13,200 v. The main generator exciters are mounted on the main shafts of their respective units and are shunt wound machines rated at 270 kw. at 250 v. On the main shaft of each unit is also mounted a 2860 kv.a., 2300-v. auxiliary house generator. These turbo-generators were furnished by General Electric Co.

Ventilation for the above generators is furnished by General Electric surface air coolers. The cooling medium is condensate or ground water for the main sections and ground water for the auxiliary sections. Provision is made for injecting inert gas through the cooling air ducts to give fire protection.

In view of the average variation of 64 ft. between high and low water of the Ohio River at the site of Columbia Power Station, the location of condensers and circulating pumps was a matter of great importance. Accordingly, a condenser well 77 ft. inside diameter and 85 ft. deep from the turbine room floor was constructed, the wall being of reinforced concrete 7 ft. thick. This installation is shown in Figs. 9 and 11. Two Worthington vertical inclined surface condensers, one for each unit, were installed, exhaust connections to the turbines being made by the exhaust stack shown in Fig. 9. Each condenser has tube sheets drilled for 50,000 sq. ft. of tube surface, with 48,000 sq. ft. installed.

On the floor of the condenser well are installed four

Principal Equipment at Columbia Power Station

General

Location of plant, about 20 mi. west of Cincinnati, O.

Capacity of installed building, 90,000 kw., ultimate, 360,000 kw.

Boiler room dimensions, 190 ft. wide, 232 ft. long, including coal preparation room.

Turbine room dimensions, 111 ft. 5½ in. wide, 174 ft. 5 in. long.

Switch house dimensions, 46 ft. 3½ in. wide, 166 ft. long.

Contractor for station construction .... The Foundation Co.

Designing Engineers, Sargent & Lundy, Inc.

Boilers, Superheaters and Economizers

6 Babcock & Wilcox Co. cross drum sectional water tube boilers. Heating surface, 15,110 sq. ft. each; tubes in two decks. Lower deck, 36 sections 8 tubes high, 3¼ in. No. 6 gage tubes, 17 ft. long. Upper deck 8 tubes high, 2 in. No. 9 gage tubes. Drums of 1⅞ in. steel, 48 in. dia., 32 ft. 10¼ in. long. Working pressure 650 lb. gage.

2 Babcock & Wilcox Co. reheat boilers, heating surface 6066 sq. ft.; working pressure, standard section 650 lb. gage. Reheat section, 17,612 sq. ft.; working pressure, 120 lb. gage. Primary superheater 1409.8 sq. ft. installed, provision for 1878.5 sq. ft.

6 Standard Babcock & Wilcox Co. interdeck superheaters, five with 2760 sq. ft. each, one with 3184 sq. ft. equipped with control damper. Total steam temperature 750 deg. F.

8 Babcock & Wilcox Co. economizers. 7300 sq. ft. of 2-in. wrought steel tubing.

8 Air-cooled pulverized coal furnaces, built by Bishop Contracting Co., arches by M. H. Detrick Co., firebrick by Chas. Taylor & Sons Co. Volume above ashpit 12,568 cu. ft.; including ash pit, 14,368 cu. ft. Tile supported from cast iron hangers; side walls cooled by secondary combustion air; ash pit walls cooled by primary combustion air.

Soot Blowers, Vulcan Soot Cleaner Co., using compressed air; 26 heads on each standard, 32 heads on each reheat boiler.

8 S-C Feed Water Regulators furnished by the S-C Regulator Mfg. Co.

Air Preheaters and Draft Equipment

8 Babcock & Wilcox Co. tubular air heaters. 9888.5 sq. ft. each; 1080 2½ in. tubes 14 ft. long.

8 Buffalo Forge Co. double inlet forced draft fans, direct connected to one 60-hp., 600-r.p.m., and one 125-hp., 750-r.p.m., 2200-v. Allis Chalmers Mfg. Co. variable speed slip ring induction motor.

8 Buffalo Forge Co. double inlet induced draft fans direct connected to one 60-hp., 600-r.p.m. and one 125-hp., 750-r.p.m. 2200-v. Allis Chalmers Mfg. Co. variable speed slip ring induction motor.

2 Fort Pitt Bridge Works steel stacks, brick-lined; south stack, serving 4 boilers 16 ft. in dia.; north stack, to serve 8 boilers 22 ft. 6 in. in dia.; height 175 ft. above boiler room floor.

8 Primary air fans, motor driven, installed in main aisle between boilers.

Coal Preparation Plant, Feeders, Burners

1 Brown Hoisting Machy. Co. automatic tripper on 36 in. belt conveyor over raw coal bunkers.

2 Fuller-Lehigh Co. indirect pulverized coal fired rotary dryers 6 ft. 6 in. dia. by 50 ft. long. 30 t. an hour. each when removing 3 per cent moisture. 2 cyclone separators, 112 in. in dia.

7 Fuller-Lehigh Co. pulverizing mills. Six 57-in. vertical gear driven screen type, 8½ t. an hour cap. each, driven by 150-hp. Allis Chalmers Mfg. Co. slip ring motors. One 70-in. vertical gear driven screen type mill; drive, 300 hp. Allis Chalmers slip ring motor, capacity 20 t. an hour.

2 Weigh bins, mounted on Fairbanks scales.

Fuller-Kinyon Transport system; three 6-in. and three 10-in. Fuller-Kinyon pumps; two-way electro-pneumatically operated valves on 8 in. transport lines; bin level indicators and control signals on control board.

40 Fuller-Lehigh Co. triplex pulverized fuel feeders, 5 per boiler, driven by Star Electric Motor Co. d. c. motors with solenoid operated clutches.

120 Fuller-Lehigh Co. flare type burners, 9 vertical and 6 horizontal burners per boiler.

Ash Disposal Equipment

1 Ash Receiving tank 40 ft. dia. by 30 ft. deep.

1 American Manganese Steel Co. ash disposal pump, 8-in., single stage, 1700 g.p.m., 150 ft. head; driven by 150-hp., 750-r.p.m., 2200-v. motor.

Boiler Feed Pump and Water Treatment System

6 Cameron Steam Pump Works centrifugal pumps, 6-stage horizontal type. Four pumps, 400 g.p.m. against 680 lb. gage, direct connected to Allis-Chalmers 400-hp., 2200-v., 1800-r.p.m. motors. Two pumps 500 g.p.m. against 680 lb. driven by Terry type C. S. 340-hp. steam turbine. Pumps governed by Mercon excess pressure regulators, furnished by D. H. Skeen & Co.

We-Fu-Go Water treatment plant installed by Wm. B. Scaife & Sons Co.; 10,000 gal. an hour capacity; four concrete reaction tanks 20 ft. dia. 19 ft. high; two concrete filter tanks 9 ft. long, 6 ft. 11 in. wide, 8 ft. deep.

2 Elliott Co. low pressure open heaters (one per unit) for 24th stage extraction 2.95 lb. abs. pressure, 1.0 per cent moisture vented to condenser.

2 Elliott Co. low pressure closed heaters (one per unit) for 22nd stage extraction 9.70 lb. abs. pressure, 77 deg. F. superheat.

2 Elliott Co. Gland heaters to condense leakage from high pressure turbine packing.

2 Elliott Co. deaerators with vapor condensers equipped with Jennings-Hytor vacuum pumps by Nash Engineering Co.

2 Open type heaters for 18th stage extraction and exhaust from feed pump turbines. Water leaves heaters at about 240 deg. and deaerators at about 215 deg.

Coal Handling Equipment

1 Mead-Morrison Mfg. Co. barge unloading tower; 375 t. an hour capacity; standard 4-t. Mead-Morrison grab-bucket, 100 t. receiving hopper. Two 75-cu. ft. per min. motor driven air compressors, Ward-Leonard variable voltage control, air operated clutches and brakes, 35-hp. barge shifting motor. Elevation of bridge 40 ft. above extreme high water, 104 ft. above extreme low water. Floating equipment, 4 landing docks 75 ft. by 26 ft., one mooring dock 110 ft. by 26 ft., furnished by Ayer & Lord Tie Co. Coal furnished in 1000-t. steel barges by Philadelphia & Cleveland Coal Co.

Coal handling system by R. H. Beaumont Co. Coal storage, 20 ft. deep, 122,000 t.; 30 ft. deep, 180,000 t.

Belt Conveyors of Goodrich "Longlife", 42-in., 7-ply, ⅛-in. rubber covered. Capacity 500 t. an hour at 170 ft. per min.

2 American Pulverizer Co. No. 60 ring crushers 250 t. an hour capacity each, driven by 100-hp. squirrel cage motors.

1 R. H. Beaumont Co. drag scraper, 4 t. capacity, driven by 150 hp. motor hoist.

1 R. H. Beaumont motor-driven tail block car running on 12 ft. gage track bounding storage area. Held by double toggle clamp.

Crib House and Service Pumps

Crib House 51 ft. 6 in. wide, 116 ft. long, 80 ft. 6 in. deep.

2 Intake tunnels, each 9 ft. 6 in. by 13 ft. 2½ in.

Principal Equipment at Columbia Power Station

2 Discharge tunnels—same as intakes.

8 Chain Belt Co. traveling screens, 82 ft. 6 in. between vertical centers, 86 ft. long overall. Each driven by 7½-hp., 1200-r.p.m., 220-v. slip ring induction motors through reduction gearing.

1 Whiting Corp. pivoted bucket crane with 1 cu. yd. bucket. Crane 18 ft. 6 in. long, 95 ft. lift.

1 Whiting Corp. 3-motor traveling crane, 46 ft. span, lift 40 ft. Capacity 35 t.

3 Allis-Chalmers Mfg. Co. ground water pumps, 8-in., single stage 2000 g.p.m., 260 ft. head, driven by 250-hp., 1760-r.p.m., 2300-v. squirrel cage motors.

2 Worthington Pump & Machy. Corp. treated water pumps; 2-in., 2-stage, 200 g. p. m., 232 ft. head; driven by General Electric Co. 30-hp., 1800-r.p.m. squirrel cage motors.

2 Worthington Pump & Machy. Corp. bilge pumps 4-in., 500-g.p.m., 90-ft. head, driven by General Electric Co., 40-hp., 1200-r.p.m. vertical squirrel cage motors.

Turbo-Generators

2 General Electric Co. tandem-compound units, 14 stages high pressure, 12 stages low. Rated capacity 45,000 kw. each, 90,000 kw. total. Steam at throttle 550 to 600 lb. gage, 750 deg. total temp.; steam leaving 14th stage, 120 lb. gage, 424 deg.; steam entering 15th stage, 110 lb. gage, 725 deg. Exhaust pressure, 1 in. mercury abs. Speed. 1800 r.p.m. Size 86 ft. long including throttle, 22 ft. 9 in. wide, 16 ft. high.

2 Main Generators, each 45,000 kw. at 0.9 p.f.; 1300 v., 3 phase, 60 cycle.

2 Main Generator exciters, each 270 kw., 250 v., shunt wound.

2 Auxiliary house generators, each 2860 kv.a., 2300-v., 3 phase, 60 cycle.

2 General Electric Co. generator air coolers, surface type; 6 main and 6 auxiliary sections for main generator; 1 main section for auxiliary house generator.

Condenser and Auxiliaries

1 Condenser Well, 77 ft. dia., 85 ft. deep.

1 Warner Elevator Co. automatic passenger elevator.

2 Worthington Pump & Machy. Corp. vertical inclined surface condensers (one per unit). Tube sheets drilled for 50,000 sq. ft., 48,000 installed.

4 Worthington Circulating pumps (2 per unit) 30,000 g.p.m. each, 27-ft. head, each driven by General Electric Co. 360 r.p.m., 325-hp., 2300-v. squirrel cage motor.

4 Worthington primary hotwell pumps, 6-in., 3-stage, 800-g.p.m. each. Driven at 1800 r.p.m. by General Electric Co. 175-hp., 2300-v. slip ring motors.

4 Worthington secondary hotwell pumps.

8 Worthington No. 8 hydraulic vacuum pumps, only 2 required at once.

4 Hurling water pumps, 8-in., 2000 g.p.m., driven by G. E. Co. 100-hp., 1200-r.p.m., 2300-v. motors.

2 Sand pumps, 6-in., 1000 g.p.m., 85 ft. head, G. E. Co., 60-hp. 900 r.p.m., 2300-v. motor.

2 Worthington bilge pumps, 4 in., 500 g.p.m., 90 ft. head, G. E. Co., 40 hp., 1200 r.p.m., 220-v. vert. squirrel cage motors.

Carrier Air Conditioning Co. ventilating equipment 12,000 cu. ft. per min. for ventilation of condenser well, 1 vent. fan, 1 air washer, 1 Breezo-fin heater.

Miscellaneous Mechanical Equipment

1 Worthington Pump. & Machy. Corp. ice melting pump, 48 in., 60,000 g.p.m., 15 ft. head, driven by 400-hp., 360 r.p.m., 2200-v. G. E. Co. motor.

3 Worthington Pump & Machy. Corp. air compressors; duplex, two-stage, size 20 by 12 by 14 in., 100 lb. gage, belt driven by G. E. Co. 270 hp., 257 r.p.m., 2200-v. synchronous motors. 2 compressed air tanks 8 ft. dia. by 20 ft. long furnished by Lasker Iron Works.

1 Whiting Corp. turbine room crane; capacity; main hoist, 110 t., auxiliary, 20 t., span 107 ft. 10 in. Runway 200 ft. long. Speeds: bridge, 150 ft. per min.; trolley, 150 ft. per min.; main hoist, 6 ft. per min.; auxiliary hoist, 40 ft. per min.

1 Layne-Ohio Co. drinking water well, about 112 ft. deep. 1 Layne vertical turbine pump, 150 g.p.m. against 100 ft. hd. 330 g.p.m. against 70 ft. hd. Receiving tank 17,000 gal. 2 high lift Allis-Chalmers pumps, Type "ST" single suction, 5 stage, 1750 r.p.m., 150 g.p.m. against 375 ft. driven by 40-hp., 220-v. motor.

2 Layne-Ohio Co. ground water wells, 1500 g.p.m. each. Two 24-in. Layne 3-stage deep well pumps, each 1000 g.p.m. against 220 ft. hd. driven by 100-hp., 1200-r.p.m., 2200-v. vertical squirrel cage motor.

Valves: Safety—Cast Steel; Manning, Maxwell & Moore, Inc., Non-Return—Angle; The Edward Valve & Mfg. Co. High Pressure Steam—Gate—The Lunkenheimer Co. Reheat Steam—The Lunkenheimer Co. High Pressure Drain. The Lunkenheimer Co. Circulating Water Valves—The Chapman Valve Mfg. Co. Payne Dean Control System The Cutler Hammer Mfg. Co.

High Pressure Steam Piping.....Pittsburgh Piping & Equipment Co.

Pipe Covering.....The Phillip Carey Co.

Irving Subway Flooring and Safstep stairways furnished by Irving Iron Works Co.

1 Turbine Oil storage Tank by Littleford Bros., 10,000 gal. capacity.

1 S. F. Bowser & Co., Inc., 500 g.p.h. turbine oil filter with Bowser rotary oil pumps. 2 S. F. Bowser & Co., Inc., 10,525 gal. transformer oil tanks. 2 S. F. Bowser & Co., Inc., 2000 gal. switch oil tanks. One 2-in. and three 1¼-in. Bowser rotary switch and transformer oil pumps, motor driven.

Electrical Equipment

13 Westinghouse E. & M. Co. Power transformers (1 spare). Each 10,000 kv.a., single phase outdoor type with Inertaire equipment. Voltage, 38,100-66,000 Y/13,200.

2 Westinghouse & M. Co. reserve station auxiliary transformers; 6000 kv.a. each, 13,200/2300-v. outdoor type.

13 Champion Switch Co. disconnecting switches. Four 3 P.S.T. 600 a., 73,000-v.; nine S.P.S.T. 600 a., 73,000-v. for 66 kv. neutral.

4 General Electric Co. oxide film 73,000-v. Form BO. Lightning arrestors.

Main and auxiliary oil circuit breakers..... Westinghouse Electric & Mfg. Co. Phases separated 12 ft.

Reactance coils.....General Electric Co.

Disconnecting Switches in Switch house..Champion Switch Co.

Generator Control Benchboard and panels and power transformer panels.....Westinghouse E. & M. Co.

3 Gould Storage Battery Co. storage batteries. Two 60-cell, 125-v., type P. O. 517 batteries for d.c. control; one 120-cell, 250-v. type P. S. 633 battery for reserve excitation and d.c. station power. This floats on d.c. coal feeder and primary air fan bus.

5 Westinghouse E. & M. Co. motor generator sets. Two for d.c. control and control battery trickle charge; generator 5 kw. 125 v., 1200 r.p.m.; motor, 8 hp., 220 v. Two sets for d.c. station power and excitation battery charging: generator 300 kw., 250-v., 1200 r.p.m.; motor 442 hp., 2300-v. induction type. One set for control battery charging: Generator 25 kw., 125-v., 1200 r.p.m., motor 37-hp., 220-v. induction type.

Transmission lines: 4 circuits of 45,000 to 50,000 kw.a. cap. each at 66,000 v. Average span 1200 ft.; 198 towers by Blaw-Knox Co.; copper, 400,000 c.m. by American Copper Products Co. Insulators by Ohio Brass & Copper Co. Line 20 mi. long.

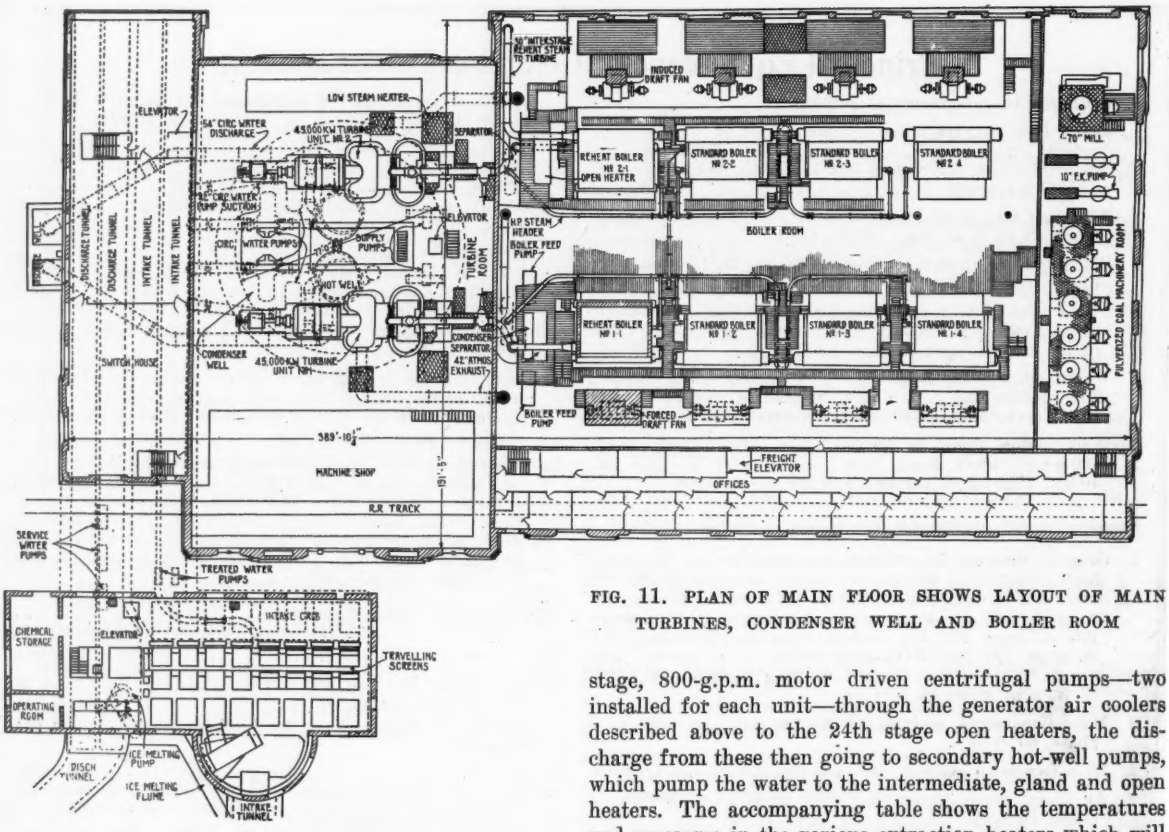


FIG. 11. PLAN OF MAIN FLOOR SHOWS LAYOUT OF MAIN TURBINES, CONDENSER WELL AND BOILER ROOM

30,000 g.p.m. circulating pumps, two for each unit, as shown in Fig. 9. When the water level is at its average point in the river, the water is practically flowing through the condensers, the pumps simply serving to overcome friction. Each pump is driven at 360 r.p.m. by a 325 hp., 2300-v. General Electric Co. squirrel cage motor.

Non-condensable gases are removed by four Worthington hydraulic vacuum pumps, only two of which are required at one time. Hurling water for these is furnished by 8-in., 2000 g.p.m. hurling water pumps, two for each unit, driven at 1200 r.p.m. by 100 hp. 2300-v. G. E. motors. A 6-in. 1000-g.p.m. sand pump is installed for each unit, designed to operate against an 85-ft. head at 900 r.p.m. and driven by a 60-hp., 2300-v. G. E. motor. Two Worthington bilge pumps are installed on the condenser well floor. For ventilating the condenser well, a Carrier air washer, ventilating fan and Breezo-fin heater are installed to supply 12,000 cu. ft. of air per minute.

TABLE SHOWING TEMPERATURES AND PRESSURES IN EXTRACTION FEED WATER HEATERS

Heater	Type of Heater	Per cent Extraction	Pressure Lb. Abs.	Water Temp. In	Deg. F. Out
24th stage	Vert. open	5.41	2.85	75	130
22nd stage	Closed	2.80	9.70	130	173
Gland	Closed	1.38	14.00	173	195
18th stage	Open	2.61	40.00	195	240

Condensate from the hot-well is pumped by 6-in., 3-stage, 800-g.p.m. motor driven centrifugal pumps—two installed for each unit—through the generator air coolers described above to the 24th stage open heaters, the discharge from these then going to secondary hot-well pumps, which pump the water to the intermediate, gland and open heaters. The accompanying table shows the temperatures and pressures in the various extraction heaters which will be described in taking up the water system.

Crib House and Tunnels Installed for Ultimate Plant

Intake and discharge tunnels, each 9 ft. 6 in. by 13 ft. 2½ in., with their bottoms 91 ft. below the turbine room floor, as shown in Figs. 9 and 11, have been installed to care for the ultimate 360,000-kw. plant. Service water and boiler feed make-up water are taken from the intake cribs, while the drinking water supply is taken from ground wells. Three 8-in. single 2000-g.p.m. stage ground water pumps, of Allis-Chalmers make, are installed in the pump room in the crib house. Two 4-in., 500-g.p.m. Worthington bilge pumps are installed in this pump room.

Water from the river enters the crib house through Chain Belt Co. traveling screens, eight of which are installed, with room for a total of 16. Figure 10D shows these screens. These screens are 82 ft. 6 in. between vertical centers and 6 ft. wide; each screen is driven through reduction gearing by a 7½ hp., 1200-r.p.m., 220-v. slip ring induction motor. Stationary grids in front of the screens collect the larger debris which is removed by a Whiting pivoted bucket crane, using a one-yard bucket and having a lift of 95 ft. This crane is pivoted at the center of the screen house and the outer end travels around the semicircular track as shown in Fig. 11. For maintenance work on screens a Whiting 35-t. crane is provided.

Water from the intake tunnels is pumped to the We-Fu-Go water treating plant, located in the crib house. This system has a capacity of 10,000 gal. per hr., using four concrete reaction tanks and two filter tanks. Lime, soda ash and ferrous sulphate are the reagents used.

Treated water pumps are 2-in., two-stage Worthington

entrifugals, driven by 30-hp. G. E. squirrel cage motors and pumping 200 g.p.m. against 232 ft. head. Treated water for make-up is mixed with the condensate in the hot well from which it is pumped by the primary hot well pumps through the generator air coolers to the 24th stage extraction heaters, located just below the main turbine room floor. These heaters are vented to the condenser and water leaving the heaters passes to the secondary hot well pumps in the condenser well. These pumps send the water to the 22nd stage closed heaters, then to the gland heaters, and then to the deaerator vapor condenser. This vapor condenser is equipped with two Jennings-Hytor motor driven vacuum pumps, designed to cut in when the pressure drops below a predetermined limit. The open type deaerator heater then takes the water, steam for this heater coming from the 18th turbine stage and exhaust at about 10 lb. gage from the turbine driven boiler feed pumps. The deaerators with the vapor condensers and open heaters are installed on the west end of the boiler room, as shown in Fig. 9, on galleries above the boiler feed pumps. These take the water from the deaerators and force it through the economizers into the boilers.

Air Compressors and Ice Melting Pump

For supplying compressed air for blowing boiler tubes, for the pulverized coal transport system, for cleaning and miscellaneous work about the plant, three motor-driven Worthington air compressors are installed in the boiler room basement.

For melting ice at the intake tunnel entrances, a 60,000 g.p.m., 15 ft. head, Worthington centrifugal motor driven pump is installed in the crib house, as shown in Fig. 11.

Electrical Equipment

Electrical equipment in Columbia Power Station has been simplified as much as possible. The control room for the station is shown in Fig. 10C. Here are located the generator control bench board, the auxiliary generator control board, the synchronizing panel and the feeder and transformer bench board. All switching is done on the 13,200-v. side of the transformers. There are thirteen Westinghouse power transformers (one used as a spare) of the single-phase outdoor type, to transform the voltage to 66,000 v. These transformers, shown in Fig. 3, are equipped with Inertaire equipment, thermometers and water flow indicators. At the right of Fig. 3 are shown the two 13,200-v/2300-v., 6000-kv.a. station auxiliary transformers, which form a reserve supply for the 2300 v. station auxiliary power. The power from the main transformers is carried on a 66,000-v. transmission line to the Hartwell Terminal Substation, shown in Fig. 8, which is located outside Cincinnati about 20 mi. from the station.

The switch house contains the main oil circuit breakers and auxiliary breakers, which are all remote-controlled and solenoid operated at 125 v. d.c. A separated phase arrangement is used here. In this switchhouse are also mounted the 15,000-v. disconnect switches. These have poles separated and located in the compartment above the corresponding phase of the oil circuit breaker with which the disconnect is used. They are remote hand operated on the same floor as the breaker compartments. The operating mechanisms are provided with interlocks so that switches cannot be opened while corresponding breaker is open. The disconnect can be locked open and when breaker is closed an interlock prevents opening of the compartment doors.

Storage Batteries Give d.c. Reserve Supply

To supply d.c. for switch operation, pulverized coal feeders, primary air fan motors, crane motors and the like, Westinghouse motor-generator sets are provided. There are two 300 kw. sets for station power, two 5 kw. sets for d.c. control and battery trickle charging and one 25 kw. set for control battery charging. For reserve d.c. station power and excitation, a 250-v. and a 125-v. Gould battery are installed. Figure 2 shows these batteries as installed in the battery room in the switch house.

A complete system of oil filters, storage tanks and pumps for turbine oil, transformer oil and switch oil has been installed by S. F. Bowser & Co., Inc.

Columbia Power Station was designed by Sargent & Lundy, Inc., Engineers, Chicago, co-operating with the engineers of the Columbia Power Co. under the supervision of C. W. DeForest, vice president and chief engineer of the Columbia Power Co. H. R. Burns is resident engineer for the company, J. V. Richards is resident engineer for Sargent & Lundy and J. H. Heimbrock is chief operating engineer of the station. We wish to thank all of these men for their assistance in obtaining data and photographs used in this article.

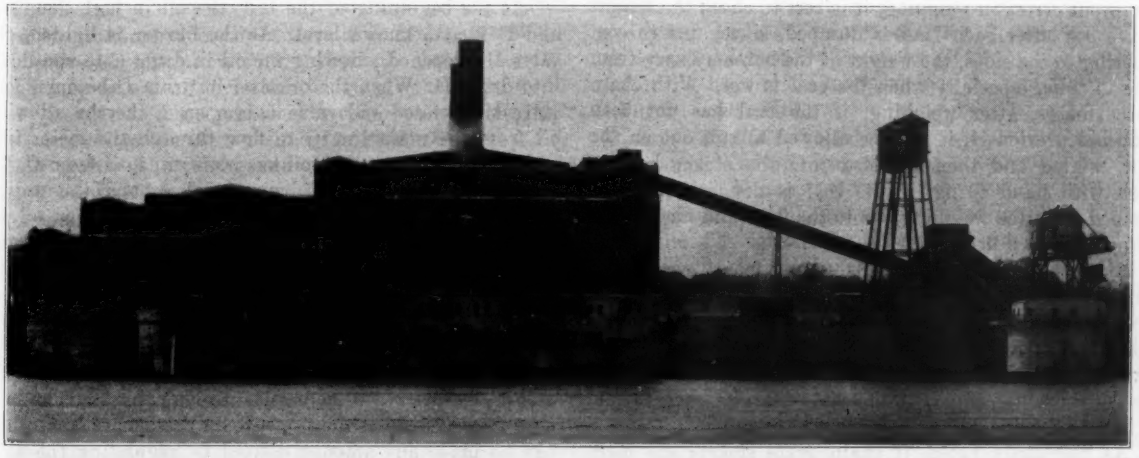


FIG. 12. COLUMBIA POWER STATION AS IT APPEARS TODAY

Fuel Measurement for Boiler Tests

Simple Yet Accurate Apparatus for Weighing Coal or Oil, Constructed at Small Cost. By D. S. Frank

WHEN CONDUCTING boiler tests, one of the most important items is an accurate weight of the fuel consumed.

In the case of coal as fuel, the apparatus is comparatively simple and, depending upon the observers, results should be accurate. As shown in Fig. 1, only a simple set-up is needed to obtain an accurate weight of coal. This may be made at small cost. From the bottom of coal bunker A a coal chute B extends into a large wooden box C, placed on platform scale D. Box C has a hinged door at the bottom to allow the coal to run out after it is weighed. The cross sectional view of the box shows how the bottom is inclined so as to allow the coal to run out readily.

Size of the box depends upon the capacity of the scale. With a scale of 1000 lb. capacity, a box should be made to hold about 600 lb. of coal, as the box, when built substantially, will weigh about 400 lb.

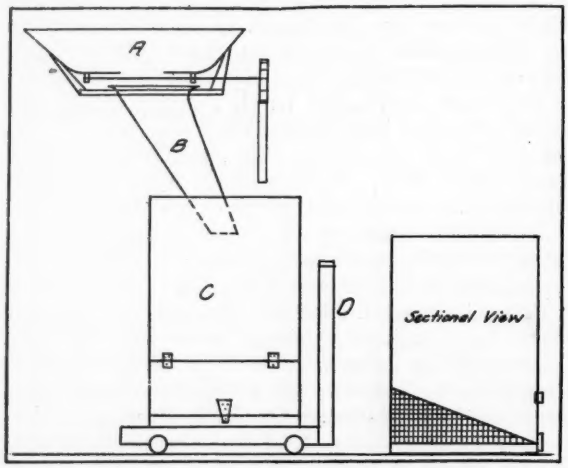


FIG. 1. COAL FROM BUNKER RUNS INTO BOX ON PLATFORM SCALE. BOX HAS DOOR AT BOTTOM FOR REMOVING COAL

When allowing the coal to run out after weighing, care should be taken that all the coal leaves the box. In order to prevent errors in weighing, it is best to check the weight of the box after each load is dumped, since, due to coal adhering to the sides, the weight of the box may vary from time to time, especially when the coal is wet. With chain grate stokers, after weighing, if the coal has not been tempered previously, it may be allowed to run out on the floor, wetted and then shoveled into the stoker hopper. Even with hand firing, if the coal is dry, it should be dumped from the weighing box to the floor and moderately tempered before firing.

Another modification of this arrangement, even better than the first method, may be made, if the coal is to be fired with stokers. A platform may be built in front of the stoker and high enough so that the coal may run from the box C directly into the stoker hopper. This eliminates the need of shoveling, which, in the case of large stokers, would be impracticable.

As previously noted, if chain grate stokers are used, the coal should be tempered in order to get the best results. If this has not been done before the coal is weighed, it may be effected by an exhaust steam spray in the stoker hopper.

Same Net Weight Desirable for Each Load

If an overhead bunker is not in use and the coal bin is on the ground floor, a wheelbarrow and a platform scale may be used directly. The coal may be shoveled into the wheelbarrow, run onto the scale, weighed, and dumped. The wheelbarrow should then be weighed empty. This weight deducted from the first weight, gives the weight of the coal.

If the coal does not adhere to the sides of the wheelbarrow when a load is dumped, it is not necessary to check the weight of the empty wheelbarrow each time. It is also a good plan to set the scales for a definite gross weight which will remain the same for each load. This will save time by eliminating the need of reading different figures on the beam for each load. Before starting to weigh coal, set the empty wheelbarrow on the scales, run the movable weight or poise out until it exactly balances the weight of the barrow and lock it in position with the thumbscrew.

Next, put weights on the scale pan to correspond to a net weight of 200 or 250 lb. of coal. Coal may then be shoveled into the barrow until the scales balance. If the scale cannot be placed near the coal bin, the barrow may be filled with approximately the correct amount, run onto the scale and coal taken off or added until the scale balances.

By having the same net weight each time, errors in reading are eliminated and round numbers like 200 or 250 may be added much more quickly than a series of uneven numbers, varying for each load.

Fuel Oil Should Be Weighed

In the case of burning fuel oil, as shown in Fig. 2, the set-up is slightly more complex. A is a wooden platform, upon which rests an ordinary platform scale B. C and D are 50-gal. drums. E is a pump driven by the motor E. F is an oil meter placed in the oil line. The oil is drawn off the main oil line G by opening the valve L, passed through the meter and run into the drum C.

At the beginning of the test, the oil in both drums C and D is at a known level. As the burner is lighted, the valve M is opened, allowing the oil in drum C to run down into drum D. When the oil level in drum C becomes low, valve M is closed and valve L is opened, thereby allowing oil from the main line G to flow through the meter into the drum. When enough oil has been run into drum C, the valve is closed, the full drum weighed, and the weight recorded. Then valve M is opened again and the oil allowed to flow into drum D. When the oil level in drum C becomes low, valve M is closed, drum C is again weighed and the weight recorded as empty. When the weight as empty is subtracted from the weight as full, the difference is the amount of oil consumed during that interval of time.

The pump takes suction from drum D through line H and discharges oil to the burner through line N. The pressure gage P denotes the pressure on the burner line, which can be made any amount desired by regulating the valve J, located on the return line to the suction barrel. By open-

ing valve J and allowing more oil to return to the barrel, the pressure on the burner line will be decreased. By closing down on the valve J, less oil will be returned to drum D and the pressure on the burner line will be materially increased. This easy method of regulating is especially desirable when the burner is called upon to take care of widely fluctuating loads.

Meter Used Only as Check on Scale

Steam coils are placed in drums C and D in order to heat the oil to the temperature desired. The meter is placed in the oil line merely to serve as a rough check on the weight as given by the scale. The temperature of the oil in drum D need not be taken, as it does not affect the weight of the oil but the temperature of the oil flowing through the meter will be necessary in order to correct the volume of oil to the standard temperature of 60 deg. F. The gravity of the oil should be taken each time a batch of

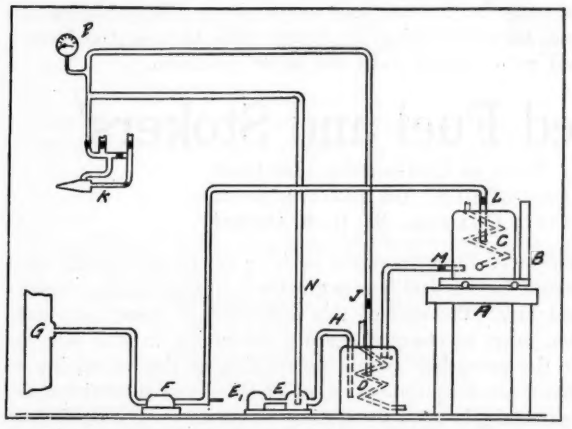


FIG. 2. OIL IS WEIGHED ON ELEVATED PLATFORM SCALE, RUN INTO RESERVOIR AND THEN PUMPED TO BURNER

oil is run into the drum. This data is necessary in order to determine the number of pounds per barrel and then convert the volume reading of the meter to one of weight in order to obtain an approximate check on the scale record.

In case an electrically-driven pump is not obtainable, a steam pump may be used, provided an air chamber is installed on the discharge line to smooth out pulsations of the pump. This installation would call for extra attention on the part of the operator and is not as desirable as an electrical set-up. With the electrical pump, it is unnecessary to watch lubrication or change the speed as the load increases. The operator has only one valve to regulate the oil to the burner since the pump runs at a constant speed. The return line to the suction drum allows circulation sufficient to keep all oil consumed at an even temperature. This is especially necessary when the oil is exceptionally heavy and the lines are exposed in cold weather.

Hourly Readings Necessary to Catch Errors

It is much more desirable to take hourly readings of the fuel consumed, whether the fuel be coal or oil, if the oil in the barrel or the coal in the stoker hopper be maintained at a certain level, on the even hour. It is easy to check the data for errors as an excessive amount of fuel burned for a certain hour will be an error in weighing unless explainable by an increase in evaporation or by some other known cause. This method will not interfere with the work, as it will make no difference how many times the oil barrel or the stoker hopper is filled during the hour, provided that, on the even hour, the level of the fuel is correct.

In order that the fuel record be accurate, it is necessary that all conditions prevailing at the beginning of the test be maintained at the even hour and at the finish.

Starting with the coal in the hopper at a given point, the coal level should be the same at the end of the run. If there is coal above this level, it should be taken out of the hopper and weighed. This weight should be then credited against the amount burned for the last hour. In the case of coal firing, it is understood, of course, that the fuel bed should be of the same thickness at end of the test as at the beginning and, if possible, from hour to hour.

Refractories for Boiler Furnaces

By Howard C. Thayer*

DISCUSSION of refractory products as applied to boiler furnace design and construction is seldom found in technical magazines, due, no doubt, to the fact that while it is one of the most important features to be considered in steam generating plants, there are few engineers connected with power plants capable of discussing this subject. In order to gain a thorough knowledge of this subject, it is necessary to study the manufacture of refractories and be able to secure a great quantity of comparative result data which usually the operating engineer is unable to obtain. Recognizing this fact, a few of the more progressive public utility operating companies have retained the services of specialists in this line and have found it a paying investment.

Refractories must be selected and the boiler furnace designed with extreme care, or else excessive maintenance costs and frequent operating shutdowns will be experienced. Such material suitable for boiler furnace service must withstand, without serious chemical or physical change, the following conditions: high and suddenly changing temperatures; considerable load, due to weight of wall and the force of expansion; destructive action of gases and impinging flames; abrasive action of the fuel dust, under forced draft; adhesion of slag and chemical reactions set up by the same. Unless the engineer has a thorough knowledge of refractories and the reactions set up by the above conditions, a high grade material may be, and frequently is, unjustly condemned.

Some of the large refractory manufacturers maintain a research department whose business, among other things, is to work out their customers' problems. In view of this, it is necessary when requesting information from them that the following data be furnished in as complete manner as possible: 1, general dimensions of the furnace; 2, description of the boiler; 3, height of walls; 4, thickness of walls and method of construction contemplated; 5, kind of fuel to be burned; 6, analysis of fuel; 7, fusion point of the ash, provided coal is to be used; 8, method of burning—hand fired, stoker, pulverized fuel, oil or gas; 9, kind of draft—positive or negative pressure in the combustion

*Engineer in charge of furnace design for the Brooklyn Edison Co.

chamber; 10, highest actual operating temperature; 11, if high temperature cement is to be used, brand and name of manufacturer. All of this information is essential if a proper recommendation is to be made by the refractory manufacturer.

There are many methods of manufacturing refractories for boiler setting use but the two leading methods only will be discussed, namely, stiff mud and dry pressed. When manufactured from carefully selected and graded flint and semi-plastic clays, the stiff mud type has a dense even structure which will resist the action of alkalies, abrasion, slag penetration and heavy loading for considerable time. They will spall rapidly, however, under sudden temperature changes and will not care for expansion and contraction without forming cracks.

Dry pressed refractories when manufactured with a medium ground body of flint clay and a semi-plastic clay binder and burned in the kiln to a temperature not less than 2400 deg. F. will withstand sudden temperature changes due to an open porous structure which permits expansions and contraction without excessive spalling. This type, however, will not stand as much load as the stiff mud type and besides will be worn away rapidly by abrasion. Slag and alkalies penetrate its pores rapidly, setting up destructive reactions since it is acid in character and when heated to a sufficient temperature can be attacked and destroyed by any material of an alkaline or basic character. This frequently happens when a low fusing ash or high sulphur coal is burned.

Heat soaking of this refractory material tends to destroy it as rapidly as any cause known. Such condition is caused by making the furnace walls too thick or by the use of insulation materials which bottle up the heat in the masonry, causing a reaction which tends to soften and break down its structure. In other words, the greater the drop in temperature and the faster the transfer of heat through the body, the longer the life of the refractory.

Since it has been proved that the use of insulation greatly increases the overall efficiency of the boiler, a means must be found of retaining the heat units and at the same time increasing the heat drop through the wall, or else reducing the furnace wall temperature. This problem has been solved by using air cooled walls to meet the former and water cooled walls the latter condition.

Economics of Pulverized Fuel and Stokers*

THERMAL EFFICIENCY ALONE IS NO REAL BASIS OF COMPARISON. DECISION SHOULD BE GOVERNED BY TOTAL STEAM COSTS WHICH ARE INFLUENCED BY THE LOAD FACTOR AND ITS BEARING ON FIXED CHARGES. BY H. S. COLBY†

COMPARISON BETWEEN pulverized fuel firing and stokers cannot be drawn by considering only the thermal efficiency of the systems. Anyone at all conversant with combustion practice would expect a higher thermal efficiency from pulverized fuel firing than from stoker firing. It is also generally recognized that this higher efficiency is obtained at the expense of the pulverizing and treatment of the coal. The various means employed for pulverizing, drying and transportation of fuel involving equipments of many designs and of varying power requirements, clouds the relationship existing between the increase in thermal efficiency and the amount it should be discounted to provide for the cost of fuel preparation.

Another important factor, is the additional investment involved for equipment, building and site for the pulverized fuel plant and the effect of this additional investment on the fixed charges applicable against the cost of power. It is also not generally recognized that the two largest items in the total cost of power are fuel and fixed charges and that until a few years ago they were almost equal. Within the last few years the ratio has changed and now fixed charges represent about one half of the total cost and fuel about one third of the total cost of power.

COMPARISON MUST CONSIDER TOTAL STEAM COSTS

To compare pulverized coal properly with stoker equipment for a given case it is necessary to arrive at the total cost of producing steam with each type of equipment. This is made up of the following items or divisions: (a) Cost of fuel; (b) Cost of power to drive combustion equipment; (c) Cost of labor and supervision; (d) Maintenance; (e) Fixed charges.

Cost of fuel depends upon the selection of the proper fuel and a station design which will give the highest net efficiency. Power required to drive driers, pulverizers, conveyors, feeders and fans is greater than that to drive stokers and fans. The cost of this difference in power consumption must be charged against the saving in coal affected by the pulverizer system in arriving at the net saving of that type of equipment. Cost of labor and supervision depends largely upon the station design and only to a limited extent on the local labor situation and management. Maintenance may vary slightly due to the skill and care of the management and operation of the station but is governed principally by the station design adopted. Fixed charges are of course, governed by the investment in plant and property.

Each of the above items of cost are influenced by the following factors, all of which must be considered in arriving at these costs: (1) Size of station; (2) Ratio of peak to station rating; (3) Load factor; (4) Use factor (as influencing load factor); (5) Provision for reliability; (6) Considerations of possible change in source, characteristics or kind of fuel.

If now we consider the effect of the above listed factors on each of the items of cost of producing steam, we will more fully appreciate the fact that the selection of the proper type of fuel burning equipment is dependent only partially upon the relative thermal efficiencies of the equipments.

Cost of fuel is to some extent influenced by each of the 6 factors listed above. It is evident that with the small plant, the fixed charges will greatly outweigh the fuel costs. This is true because provisions for reliability make the investment relatively large and the fixed charges rather than the fuel cost becomes the paramount consideration. Again consider the base load station of one of our modern, interconnected, super power systems. In the operation of this station the cost of fuel represents a large item and it must, therefore, be given the closest scrutiny. Between these two extremes the problem of selection of equipment in so far

*From a paper presented before the Providence Section A.I.E.E., Dec. 10, 1925.

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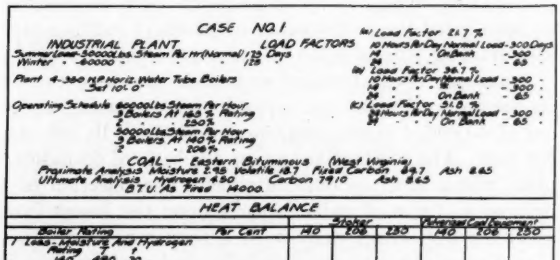
as its effect on fuel cost is concerned, is of more or less importance depending on the relationship in size of plant to the extremes used in this illustration.

Load factor influences the cost of fuel and in the new design of the base load station of an inter-connected power system every effort must be made to increase the efficiency with a view of reducing fuel cost to a minimum. As the other extreme, consider the steam stand-by station of a combined hydro-electric and steam generating system. The load factor does not justify the extreme in economy. In such a station the fuel cost can be sacrificed to lower fixed charges because of the greater proportion of the total cost represented by these fixed charges. Load factor has a direct bearing on the selection of the fuel burning equipment only in so far as it influences the rate of heat liberation required within the furnace. It may cover long periods of operation at moderate ratings or short periods of operation at extremely high ratings and long periods on bank. Even from this viewpoint the possible saving that might be effected through the adoption of an equipment more economical under bank represents but a small proportion of the total cost of fuel.

Provision for reliability has considerable bearing in the selection of equipment for the moderate size plant. Where the number of steam generating units are few it is highly


CASE NO. 1

INDUSTRIAL PLANT — LOAD FACTORS — (a) Load Factor 21.7%

Summer Load-50000 lbs. Steam Per Hr (Normal) 12 Days — 10 Hours Per Day Normal Load-300 Days
Winter " -60000 " 12 " — N " " On Bank -300
" -120000 " 1 " — M " " " -65

Plant-4-350 HP Horiz. Water Tube Boilers — (b) Load Factor 36.7%
Set 12'-0" — 10 Hours Per Day Normal Load - 300
N " " - 300
M " On Bank - 65

Operating Schedule 50000 lbs Steam Per Hour — (c) Load Factor 54.2%
3 Boilers At 160% Rating — 14 Hours Per Day Normal Load - 300
250% — N " " On Bank - 65
50000 lbs Steam Per Hour
3 Boilers At 140% Rating
2 " 206%

COAL — Eastern Bituminous (West Virginia)
Proximate Analysis Moisture 2.96 Volatile 18.7 Fixed Carbon 69.7 Ash 8.65
Ultimate Analysis Hydrogen 4.50 Carbon 79.10 Ash 8.65
B.T.U. As Fired 14000

HEAT BALANCE

Boiler Rating	Per Cent	Stoker 140	Stoker 206	Stoker 250	Pulverized Coal Equipment 140	Pulverized Coal Equipment 206	Pulverized Coal Equipment 250
1 Loss-Moisture And Hydrogen							
Rating							
140	4.90						
206	5.30						
250	5.80						
		3.6	3.6	3.7	3.6	3.6	3.7
2 Loss-Dry Gases							
Stokers: Rating (T-1)	CO2 CO O2 N2						
140	13.0 0.0 7.0 80						
206	13.5 " 6.5 "						
250	13.3 " 6.5 "						
Pulverized Coal Equipment:							
	CO2 CO O2 N2						
	14.3 0.0 5.3 80.0						
	14.0 " 5.7 "						
	13.5 " 6.8 "						
		11.0	11.8	12.4	10.6	11.2	12.0
3 Loss-Carbon In Ash							
Rating	Per Cent Carbon In Ash	Per Cent Ash In Coal					
140	10.0	8.65					
206	24.0	"					
250	27.0	"					
		2.3	2.9	3.3			
3A Loss In Incomplete Combustion					1.8	1.9	2.1
4 Loss-Radiation & Unaccounted For		5.8	5.0	4.7	5.8	5.0	4.7
5 Heat Absorbed By Boiler		77.3	76.7	76.9	78.2	78.9	77.5
6 Efficiency Operating		78.9	79.0	77.0	76.0	76.0	76.0
7 Margin Between Test And Operating Efficiency		3.6	3.7	3.9	2.2	2.3	2.0

FIG. 1. FOR A PLANT GENERATING 50,000 LB. STEAM PER HR. COMPARISON OF EFFICIENCY BETWEEN STOKERS AND PULVERIZED FUEL FIRING IS SHOWN IN THIS TABLE

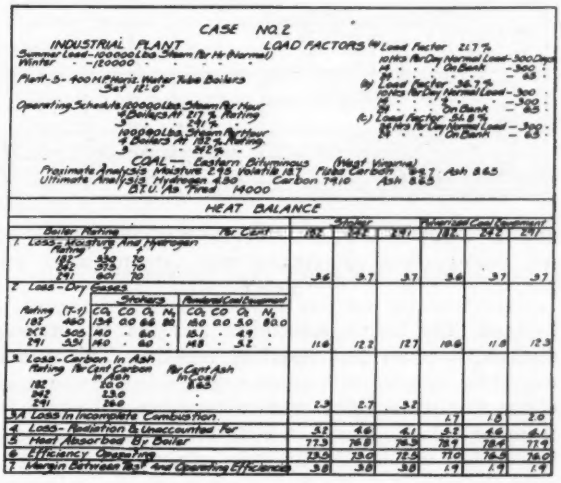
desirable that the equipment selected should be reliable not alone in its inherent design as represented by the recognized necessity for replacement of wearing parts, but also in the ability to forecast outage periods. In a plant of moderate size reliability will often outweigh fuel saving.

Possibilities of changing the source of fuel supply and obtaining a different grade of coal or of changing to some other fuel, for instance oil, influences fuel cost and the selection of equipment for the utilization of the usual fuel at the lowest cost.

Power to drive combustion equipment varies directly with the tonnage of fuel prepared for any given fuel. This cost, therefore, is affected by the same factors as the fuel cost. For a given rate of coal preparation the power required varies with different coals, principally increasing greatly with the moisture content. It is, therefore, highly important to consider what coal or coals will have to be prepared and handled.

Load Factor Influences Fixed Charges

We have now reached the item of fixed charges which in arriving at the total cost of steam must include interest on the investment in plant, taxes, insurance, depreciation and obsolescence. Based on a reasonable life for the equipment and buildings and on present day costs of financing, taxes and insurance, the sum total of these charges will


CASE NO. 2

INDUSTRIAL PLANT — LOAD FACTORS — (a) Load Factor 21.7%

Summer Load-100000 Lbs Steam Per Hr (Normal) — 10 Hrs Per Day Normal Load-300 Days
Winter " -120000 " — N " " On Bank -300
— M " " " -65

Plant-5-400 HP Horiz. Water Tube Boilers — (b) Load Factor 36.7%
Set 12'-0" — 10 Hrs Per Day Normal Load - 300
N " " - 300
M " On Bank - 65

Operating Schedule 100000 Lbs Steam Per Hour — (c) Load Factor 54.2%
4 Boilers At 217% Rating — 14 Hrs Per Day Normal Load - 300
217% — N " " On Bank - 65
100000 Lbs Steam Per Hour — M " " " -
4 Boilers At 182% Rating
3 " 242%

COAL — Eastern Bituminous (West Virginia)
Proximate Analysis Moisture 2.96 Volatile 18.7 Fixed Carbon 69.7 Ash 8.65
Ultimate Analysis Hydrogen 4.50 Carbon 79.10 Ash 8.65
B.T.U. As Fired 14000

HEAT BALANCE

Boiler Rating	Per Cent	Stoker 182	Stoker 242	Stoker 291	Pulverized Coal Equipment 182	Pulverized Coal Equipment 242	Pulverized Coal Equipment 291
1 Loss-Moisture And Hydrogen							
Rating							
182	5.30						
242	5.70						
291	6.01						
		3.6	3.7	3.7	3.6	3.7	3.7
2 Loss-Dry Gases							
Stokers: Rating (T-1)	CO2 CO O2 N2						
182	13.4 0.0 6.6 80						
242	14.0 " 6.0 "						
291	13.9 " 6.0 "						
Pulverized Coal Equipment:							
	CO2 CO O2 N2						
	15.0 0.0 5.0 80.0						
	15.1 " 4.9 "						
	14.8 " 5.2 "						
		11.6	12.2	12.7	10.6	11.8	12.3
3 Loss-Carbon In Ash							
Rating	Per Cent Carbon In Ash	Per Cent Ash In Coal					
182	10.0	8.65					
242	13.0	"					
291	16.0	"					
		2.3	2.7	3.2			
3A Loss In Incomplete Combustion					1.7	1.8	2.0
4 Loss-Radiation & Unaccounted For		5.2	4.6	4.1	5.2	4.6	4.1
5 Heat Absorbed By Boiler		77.3	76.8	76.5	78.9	78.6	77.9
6 Efficiency Operating		79.5	79.0	77.5	77.0	76.5	76.0
7 Margin Between Test And Operating Efficiency		3.8	3.8	3.8	1.9	1.9	1.9

FIG. 2. COMPARATIVE EFFICIENCY AT 100,000 LB. STEAM PER HOUR

average between 12 and 14 per cent on the initial investment. It should, therefore, be apparent that the higher the initial investment the higher will be the sum of fixed charges which must be distributed on the basis of the station output.

Consider now the effect of station size. The small plant costs more per horsepower or kilowatt-hour than the large plant, due to the size of units and the percentage of spare capacity required to provide for outage. It is, therefore, evident that care should be exercised in the selection of the number and size of boiler and generating units so that the ratio of peak load to station rating shall be a minimum.

Load factor plays a considerable part in the determination of fixed charges per unit of station output. The station with the highest load factor has the minimum fixed charges per unit of output. The determination of load factor is of the highest importance.

Exception may be taken to the opinion that the same number and size of boiler units should and can be used with either equipment. In comparing pulverized fuel burning equipment with stokers, in many instances, efforts have been made by the advocates of the pulverized fuel burning equipment to advance the assumption that this equipment will carry higher ratings than stokers and accordingly either the number of boiler units or the size of the units might be reduced with a resulting saving in the initial investment. This argument has been advanced to offset in part the additional cost of the bin system of pulverized fuel firing as compared with the complete modern stoker equipment. As a matter of fact there is no basis for such a conclusion.

Maintaining proper capacity or rating is purely a matter of proportioning the fuel burning equipment to the

CASE NO. 3

INDUSTRIAL PLANT — LOAD FACTORS (a) Load Factor 21.7%

Summer Load - 150000 Lbs. Steam Per Hr. (Normal) — 10 Hrs. Per Day Normal Load - 300 Days
Winter " - 180000 " " " 14 " " On Bank - 300
" - 65
Plant - 3 - 575 H.P. Horiz. Water Tube Boilers Set 14'-0" (b) Load Factor 36.7%
10 Hrs. Per Day Normal Load - 300
14 " " On Bank - 300
" - 65
Operating Schedule 180000 Lbs. Steam Per Hour 4 Boilers At 125% Rating 3 " 100% "
150000 Lbs. Steam Per Hour 4 Boilers At 104% Rating 3 " 125% " (c) Load Factor 51.8%
24 Hrs. Per Day Normal Load - 300
On Bank - 65

COAL — Eastern Bituminous (West Virginia)
Proximate Analysis Moisture 2.95 Volatile 18.7 Fixed Carbon 69.7 Ash 8.65
Ultimate Analysis Hydrogen 4.50 Carbon 79.10 Ash 8.65
B.T.U. As Fired 14000

HEAT BALANCE

Boiler Rating	Per Cent	Stoker			Pulverized Coal Equipment		
		184	250	302	184	250	302
1. Loss - Moisture And Hydrogen							
Rating 184	503 70						
250	540 70						
302	573 70						
		3.6	3.7	3.7	3.6	3.7	3.7
2. Loss - Dry Gases							
Stokers: Rating (T-1)	CO_2 CO O_2 N_2						
184	13.7 0.0 6.3 80						
250	14.7 " 5.8 "						
302	14.7 " 5.3 "						
Pulverized Coal Equipment	CO_2 CO O_2 N_2						
	13.2 0.0 4.8 80						
	15.2 " 4.8 "						
	14.8 " 5.2 "						
		10.6	11.1	11.4	9.7	10.5	11.5
3. Loss - Carbon In Ash	Per Cent Carbon In Ash	Per Cent Ash In Coal					
184	14.0	8.65					
250	22.0	"					
302	25.0	"					
		2.1	2.6	3.0			
3A. Loss In Incomplete Combustion					1.5	1.7	1.9
4. Loss - Radiation & Unaccounted For		4.7	4.0	3.5	4.7	4.0	3.5
5. Heat Absorbed By Boiler		74.0	78.6	78.4	80.5	80.1	79.4
6. Efficiency Operating		76.0	78.0	74.5	78.5	78.0	77.5
7. Margin Between Test And Operating Efficiencies		4.0	3.6	3.9	2.0	2.1	1.9

FIG. 3. WHEN THE PLANT OUTPUT WAS 150,000 LB. PER HR. COMPARATIVE EFFICIENCY WAS AS SHOWN IN THIS TABLE

CASE NO. 4

INDUSTRIAL PLANT — LOAD FACTORS (a) Load Factor 21.7%

Summer Load 200000 Lbs. Steam Per Hr. (Normal) — 10 Hrs. Per Day Normal Load - 300 Days
Winter " 230000 " " " 14 " " On Bank - 300
" - 65
Plant 3 - 740 H.P. Horiz. Water Tube Boilers Set 16'-0" (b) Load Factor 36.7%
10 Hrs. Per Day Normal Load - 300
14 " " On Bank - 300
" - 65
Operating Schedule 230000 Lbs. Steam Per Hour 4 Boilers At 225% Rating 3 " 100% "
200000 Lbs. Steam Per Hour 4 Boilers At 197% Rating 3 " 265% " (c) Load Factor 51.8%
24 Hrs. Per Day Normal Load - 300
On Bank - 65

COAL — Eastern Bituminous (West Virginia)
Proximate Analysis Moisture 2.95 Volatile 18.7 Fixed Carbon 69.7 Ash 8.65
Ultimate Analysis Hydrogen 4.50 Carbon 79.10 Ash 8.65
B.T.U. As Fired 14000

HEAT BALANCE

Boiler Rating	Per Cent	Stoker			Pulverized Coal Equipment		
		197	265	300	197	265	300
1. Loss - Moisture And Hydrogen							
Rating 197	508 70						
265	550 70						
300	572 70						
		3.6	3.6	3.7	3.6	3.6	3.7
2. Loss - Dry Gases							
Stokers: Rating (T-1)	CO_2 CO O_2 N_2						
197	13.8 0.0 6.0 80						
265	14.8 " 5.5 "						
300	15.0 " 5.0 "						
Pulverized Coal Equipment	CO_2 CO O_2 N_2						
	13.3 0.0 4.7 80						
	15.2 " 4.8 "						
	15.0 " 5.0 "						
		10.7	11.3	11.8	10.0	10.9	11.6
3. Loss - Carbon In Ash	Per Cent Carbon In Ash	Per Cent Ash In Coal					
197	14.0	8.65					
265	22.0	"					
300	25.0	"					
		2.1	2.6	3.0			
3A. Loss In Incomplete Combustion					1.2	1.4	1.6
4. Loss - Radiation & Unaccounted For		3.8	3.0	2.7	3.8	3.0	2.7
5. Heat Absorbed By Boiler.		74.8	74.5	74.4	81.4	81.1	80.4
6. Efficiency Operating		76.0	75.8	75.5	74.5	74.0	78.5
7. Margin Between Test And Operating Efficiencies		3.8	4.0	3.9	1.9	2.1	1.9

FIG. 4. STOKERS AND PULVERIZED FUEL FIRING WHEN PRODUCING 200,000 LB. STEAM PER HR. GAVE THE COMPARATIVE RESULT SHOWN BY THESE FIGURES

furnace. The boiler, economizer and the air preheater represent a given heat absorbing capacity. This capacity cannot be exceeded without an appreciable decrease in efficiency of the absorbing units with either pulverized fuel firing or stokers. It is true, however, that the heat absorbing surface will be slightly more efficient when using the pulverized fuel burning equipment due to the higher quality of gas obtainable and usually carried in pulverized fuel installations. In either case, however, capacity is practically uniform and just as high ratings have been obtained with modern stokers as with pulverized coal equipment.

In setting up a comparison of equipment, the initial costs of both stoker and pulverized fuel furnaces will be burdened with some form of protected furnace wall construction (either air or water cooled) and the capacities and efficiencies obtainable with pulverized fuel equipment and stokers will be based on such furnace design and construction.

Consideration of the efficiency of fuel burning equipment should be based on the quality of gas and ash obtainable. The highest thermal efficiency is obtained from that equipment which will burn the fuel with the lowest per cent of excess air and with the smallest loss of combustible in the ash. With furnaces of a design and construction that do not limit either stoker or pulverized fuel burning equipment in temperatures evolved, the efficiency is largely dependent on the highest percentage of CO_2 that can be carried without appreciable CO and, at the same time, a reduction in the loss due to combustible in the ash to a minimum. Assumption of gas and ash quality obtainable with stokers and pulverized fuel firing are based on a careful survey of the data available in modern and representative pulverized fuel burning plants and of the performance of representative modern stoker plants.

In preparing the comparison of equipments, the efficiencies at the different operating ratings were obtained from heat balances based on assumed CO_2 and combustible in the ash values representative of present day practice. These values for the stokers are entirely consistent with actual results obtained by tests on several typical modern units with multiple retort underfeed stokers. These tests were made on stokers in which are embodied recent improvements and developments in stoker design.

Trend of Costs Shown in Four Cases

To establish the trend of costs with stokers and pulverized fuel firing equipments under parallel conditions we have listed the performance of plants of varying capacities starting with a plant of normal output of 50,000 lb. of steam per hour. Detailed estimates have been prepared on the costs of plant operation in plants having an output of 50,000, 100,000, 150,000 and 200,000 lb. of steam per hour. The assumptions are on the basis of an industrial plant which must be self-contained. The selection of the number and size of units depends upon the lowest investment for a given capacity with a proper reserve. An explanation of the basis can best be made by reference to Fig. 1, in which Case 1 is presented.

Tables Show Summary of Results

On the performance as established by heat balance the weight of coal burned per year was obtained for each case for each of the load factors indicated. To increase the value of the data presented we have prepared two separate and distinct summaries which are alike in all respects except the price of fuel. These are shown in Figs. 5 and 6. The first summary of operating cost is on the basis of coal at $4.50 per net ton, a price which is representative of coal delivered at tide water, the lowest representative price obtaining in New England; the second tabulation or summary is based on the cost of operation with coal at $6.00 per net ton, which is representative of coal delivered by rail at inland points. The weights of coal obtained for each case are entered in the tabulation.

From data available on the power required for driving of stokers and forced draft fans the power requirements for stoker and fan drive were established. This varied but slightly from 10 kw-hr. per ton of coal burned, the variation being on the lower side. Taking 10 as a base, however, is doing but slight injustice to the stoker equipment. The power required for the preparation, distribution and feeding of coal in pulverized form varied considerably. A careful analysis revealed that with high grade Eastern coals the power requirements were less than with Western coals. This figure was finally established at 20 kw-hr. per ton of coal as representative of the size and type of plants and

fuel under consideration. The cost was based on 1 cent per kw-hr.

Maintenance, likewise established by a careful analysis of operating costs of stoker and pulverized fuel firing plants, and indicated in the summary is for stokers and furnace brickwork, for pulverized fuel firing equipments and for furnace construction. Cost of labor and supervision will be approximately the same with either type of equipment and this item can, therefore, be omitted from the comparison.

Fixed charges does not include the fixed charges on buildings or equipment which are not changed or modified with either pulverized fuel or stokers, except as specifically mentioned. To obtain this item, therefore detailed estimates were prepared on the costs of stoker and pulverized fuel firing plants on the following basis: Boilers are of the same number and size, and set the same height from basement floor to under side of header. In the case of the stoker fired plant the operating floor is raised above the basement in a sufficient amount to provide space for ash storage capacity, ash conveyors, air ducts and fan equipment. The proportioning of the house is such as to afford a reasonable aisle at the rear and sides of the boilers, and a firing aisle of such width as would be required for stoker operation.

With the pulverized fuel firing equipment the same total height from basement floor to under side of boiler header was assumed. On the smaller units it was assumed that the ash could be permitted to accumulate in the bottom of the furnace for periodical removal. In the larger units the furnace was provided with a hoppered bottom terminating in an ash sluice or ash drag for the daily removal of ash. The dimensions of the boiler house proper are identical. The increased investment for building was established on a basis of providing either a separate preparation house or of increasing the cubical contents of the boiler house in a sufficient amount to provide for the proper housing of the preparation equipment.

Proportioning of the boiler house for the stoker was such as to afford a raw coal bunker above the firing aisle. With the pulverized fuel plant the pulverized coal storage bins and feeders together with the operating gallery occupy the space given to the raw coal bunker in the stoker fired boiler house. The extra space necessary for the preparation house, therefore, included the space required for the raw coal bunker. The costs of stoker and pulverized fuel installations are taken on the basis of prevailing costs of equipments. A typical detailed estimate included the following items:

Stoker Equipped Plant

Stokers complete with drive equipment.

Motors (for stoker drive) with control.

Wiring.

Water cooled bridge walls including boiler connecting tubes.

Fans including 50 per cent reserve capacity.

Motors (for fan drive) complete with control.

Wiring.

Air ducts, blast gates, supports.

Ash hoppers of the cast-iron suspended type with gates, cars and trackage.

Boiler brickwork including furnace blocks.

Pulverized Fuel Equipped Plant

Preparation, transportation and burning equipment.

Boiler brickwork (hollow wall or ventilated type).

Separate preparation building complete including foundations and pipe tunnel to boiler house.

Slag screens or hoppered bottom for continuous ash removal.

Ash sluicing system or drag ash conveyor with gates.

Fixed charges directly applicable to each equipment were taken on the basis of 13 per cent which is probably an average for present costs of financing, taxes, insurance, and what is usually provided for obsolescence. As a matter of fact 13 per cent is probably not high enough in the light of the charge that should be made for obsolescence under conditions that exist today in the development of the art of producing steam. With the trend toward higher pressures, the use of mercury as a heat transfer medium, and the possibilities of a wider adoption of gas and oil engines, it is almost impossible to foresee what developments might take place which would have a direct bearing on the factor of obsolescence.

Total costs of producing steam for each case and at

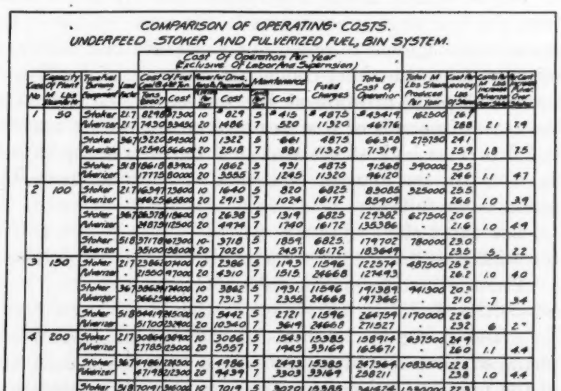

COMPARISON OF OPERATING COSTS.
UNDERFEED STOKER AND PULVERIZED FUEL, BIN SYSTEM.

FIG. 5. WHEN COAL IS $4.50 PER TON, OPERATING COSTS OF STOKERS AND PULVERIZED FUEL COMPARE AS SHOWN BY THESE FIGURES

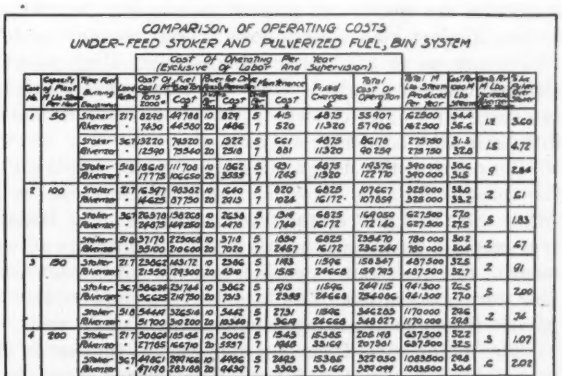

COMPARISON OF OPERATING COSTS
UNDER-FEED STOKER AND PULVERIZED FUEL, BIN SYSTEM

FIG. 6. AT $6.00 PER TON OF COAL, THE COMPARISON OF OPERATING COSTS OF STOKERS AND PULVERIZED FUEL IS LIKE THIS

each load factor and at the prices previously mentioned, have been entered in the respective summaries. These values divided by the number of thousands of pounds of steam produced in a year in the plant in question, gives the total cost per thousand pounds of steam at each of the several load factors. The next column in the summaries shows the cents per thousand pounds increase in cost of steam generated with pulverized fuel equipment over the cost as generated with stokers. The last column shows the per cent increase. It will be observed that in the second summary based on coal at $6.00 a ton that for case 4-A on the 21.7 per cent load factor that the cents increase and per cent increase in cost of pulverized fuel firing over stoker firing is shown as a minus quantity. This indicates that for this case and load factor, the cost with the pulverized fuel firing is lower than with stokers.

From these four examples we can establish the approximate trend of the cost of steam with stokers and pulverized coal. Continuing the calculations on the basis established by these detailed figures for the four cases shows that in the isolated plant and with coal at $4.50 a ton the bin system of pulverized coal firing is not justified until the size of the station expressed in evaporation of pounds of steam per hour is in the vicinity of 500,000 to 600,000 lb. With coal at $6.00 a ton the bin system of pulverized coal firing is not justified until the station is of a capacity in the vicinity of 300,000 to 400,000 lb. of steam.

With the central station the stokers show a lower cost of steam generation with coal at $4.50 a ton up to somewhere in the vicinity of 400,000 to 500,000 lb. of steam per hr. With coal at $6.00 a ton the point up to which stokers show a lower cost of steam generation is in the vicinity of 200,000 to 300,000 lb. per hr. It is impossible to draw a line of demarcation due to the influence of the many variables including the initial investment.

Pulverized Fuel Must Meet These Requirements

To broaden the field of application of pulverized coal firing and to extend the application of this equipment into the sphere which we have defined as that properly belonging to the underfeed stoker, it will be necessary to develop pulverized fuel firing equipments having the following characteristics:

An equipment in which the initial investment does not exceed that or very slightly exceeds that of stoker equipment: in which the power required for driving the equipment closely approaches that required for the driving of stokers and forced draft fans; in which coals of high moisture content can be pulverized without pre-drying; in which the cost of maintenance is comparable with stoker equipment and in which normal wear is of such nature as to enable the operator to anticipate outage periods.

Burner or furnace equipment design must be such as to reduce the size of furnace required so that it will be more comparable in size with the furnace of the stoker installation. The reduction in furnace size is necessary with a view of reducing initial investment and maintenance.

At present, the type which gives promise of sufficient development to meet the requirements as outlined above, is "unit type" of pulverized fuel firing equipment.

New Developments in High Vacuum Apparatus*

A Discussion of the More Important Developments in the Design and Use of Steam Jet Vacuum Producing Equipment. By G. L. Kothny

STEAM JET air pump type of vacuum producing apparatus has been in general use for a number of years and has been adopted as a standard for marine and stationary power plants. During the past six years, however, considerable developments have been made in the design and performance of the steam air ejector and it is the object of this paper to record the most important ones.

Steam air ejectors at present in use, can be grouped in two distinct classes as follows: Low vacuum ejectors (for vacua up to 25½ in.); Single-stage. High vacuum ejectors (for vacua above 25½ in.); two-stage straight; two-stage with inter-condenser; two-stage with combined inter and after-condenser augmenters.

Considering the design of steam nozzles employed in the construction, the above-mentioned ejectors can be of either the "Radojet" or the "Leblanc" type. The Radojet type employs an annular nozzle which permits the adjustment of the live steam expansion and the entrainment surface during operation. The Leblanc type employs tubular nozzles throughout, arranged either singly or in nests.

The recent wide discussion and general interest in the use of high pressure and high temperature steam have brought into prominence the matter of closed feed-water systems. In these the condensate is preheated to within 20 to 50 deg. of the evaporation temperature by means of stage heaters.

Since the inter- and after-condenser of an air ejector are excellently fitted to serve as a stage heater, the use of steam air ejectors with inter- and after-condensers was given more consideration and brought about further development of this type.

By arranging an inter-condenser between the first and second stage the steam consumption of the two-stage ejector can be reduced about 50 per cent. The live steam issued from the first stage is condensed in the inter-condenser and the second stage has to remove only the saturated air vapor mixture from the inter-condenser. For example, if at a certain absolute pressure at the suction of the first stage the ratio of pounds of live steam to pounds of air removed is 2.2 to 1 in both stages and if G lb. of free air have to be removed, the amount of steam, S, required to do this would be as follows:

For the 2-stage ejector:

$$S = 2.2G + 2.2^2 \times (G + x) = 7.04 \times G + 4.84 + x$$

For the 2-stage ejector with inter-condenser:

$$S = 2.2G + 2.2 \times (G + x_1) = 4.4 \times G + 2.2 \times x_1$$

x and x_1 are the amounts of vapors contained in each pound of air removed in accordance with the Dalton Law at the pressure and temperature existing at the suction of the second stage. x will be greater than x_1 as the latter can be reduced to a minimum by supplying sufficient circulating water of low temperature to the inter-condenser.

From the above it is evident that the reduction in steam consumption is obtained in the second stage only, and that the second stage of an inter-condenser ejector has only about 0.4 of the capacity of the second stage of a

*Read at the 83rd general meeting of the Society of Naval Architects and Marine Engineers, New York, Nov. 12 and 13, 1925.

two-stage straight ejector, handling the same amount of air with both stages operating. The second stage alone is used for the evacuation of the condenser from atmospheric pressure to about 21 in., at which vacuum the first stage is brought into operation. Due to the smaller capacity of the second stage, the evacuation time will be two and a half times longer unless an additional second stage is put into operation.

The design of an inter-condenser requires the following considerations: 1. The ratio of air to steam is about 1000 times larger than that in the main condenser. 2. Due to this condition, different principles must be applied in its design. 3. The air vapor mixture withdrawn by the second stage must be absolutely free from entrained water globules. 4. This necessitates substantially complete separation of the condensate from the air undergoing compression.

In Fig. 1, a steam air ejector with surface inter-condenser of the Radojet type is shown. The design of the inter-condenser is original and embodies the considerations outlined above.

The air to be compressed enters into the suction chamber of the first stage, where it is acted upon in known manner by the steam issuing in jets from tubular nozzles. The mixture of air and steam is delivered through the diffuser

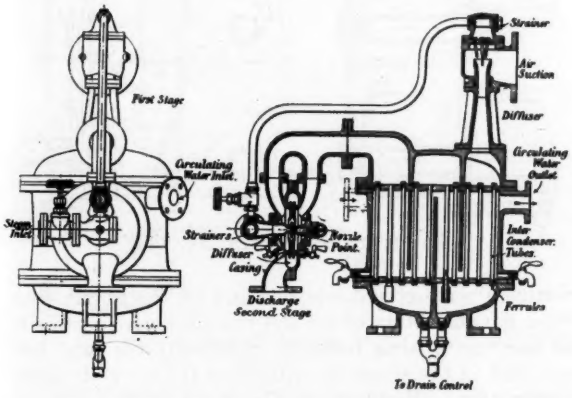


FIG. 1. A STEAM JET EJECTOR WITH A SURFACE CONDENSER OF THE RADOJET TYPE

into the upper chamber of the condenser and passes downward through the first group of condenser tubes around which is flowing the cooling water, condensing most of the steam. The condensate remains in the lower chamber and passes off through a pipe into the drain control, while the air and steam continue their passage upward through the second group of condenser tubes, where the mixture is further cooled and a further portion of the vapor is condensed. The condensate drips downward through drain tubes into the lower chamber. The air and remaining vapors descend through a third group from the upper chamber into the lower chamber (the condensate passing off through drain pipes into the drain control) and from there pass upwards through a fourth group of tubes and the upper chamber into the suction chamber of the second stage, where they are compressed to above atmospheric pressure in the well-known manner.

Any condensate collecting on the upper tube sheet runs off through drain tubes which at the lower end have a water seal, thus maintaining the upper and lower chambers isolated from each other as to their pressure conditions.

The arrangement of a vertical surface condenser between stages of a multiple stage ejector with the air passing through the tubes has the following advantages: 1. Complete separation of the condensate from the air is obtained. 2. The velocity of the air passing through the tubes can be controlled by the arrangement of a certain number of tube passes, and thereby the best possible heat transfer can be obtained. 3. The steam jet issued from the first stage flows parallel to the tubes, instead of at right angles, as in ordinary surface condensers. This eliminates erosion of the condenser tubes, which is a common occurrence in surface inter-condensers of the ordinary type. If sufficient baffle plates are arranged to prevent erosion, such baffles cause a pressure drop in the inter-condenser, with a subsequent loss of efficiency in the performance of the ejector.

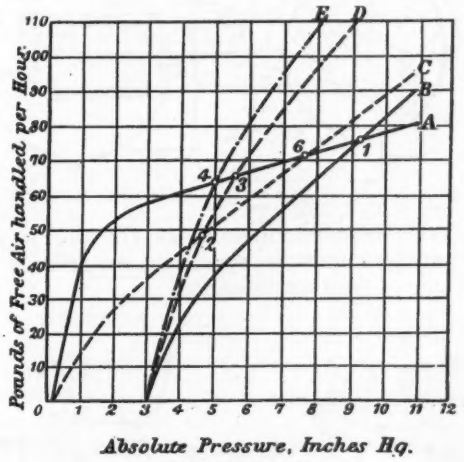


FIG. 2. PERFORMANCE CHARACTERISTICS OF THREE DIFFERENT TYPES OF AIR EJECTORS ALL HAVING THE SAME STEAM

The condensate from the inter-condenser is automatically returned to the main condenser by a vacuum drain control or through a syphon pipe if sufficient vertical height is available.

The performance characteristics of a steam air ejector with inter-condenser are somewhat different from that of the two-stage ejector without inter-condenser.

Figure 2 illustrates the performance characteristic of three different types of air ejectors, all having the same steam consumption. The ordinates give the amount of air compressed in pounds per hour, the abscissa the absolute pressure in inches mercury. Curve A shows the performance of a two-stage ejector with inter-condenser with both stages in operation; curve B the same, but with only the second stage in operation. The temperature of the circulating water for the inter-condenser on which these curves are based is 80 deg. F. at the inlet. Curve C shows the performance of a two-stage ejector without inter-condenser with both stages in operation, and curve D the same with the second stage only in operation. Curve E shows the performance of a single-stage ejector, having the same steam consumption as both stages of the two aforementioned ejectors.

It will be noted that curves A and B of the inter-condenser ejector cross each other at point 1 or at about 9 in. absolute pressure. This indicates that, when using a steam air ejector with inter-condenser, it is of no advantage to have the first stage in operation when the vacuum is less than 21 in.

Curves C and D of the two-stage ejector cross each other at point 2, which is located much farther to the left at about 4.5 in. absolute. With this type of ejector no advantage is gained from operating the first stage, when the vacuum is less than 25½ in. Curve D crosses curve A at point 3 or at 5½ in. absolute, above which absolute pressure the second stage of the two-stage ejector without inter-condenser has considerably larger air-handling capacity than the two-stage ejector with inter-condenser. Curve E crosses curve A at point 4, which is located at about 5 in. absolute, and curve A crosses curve C at 6 in. absolute.

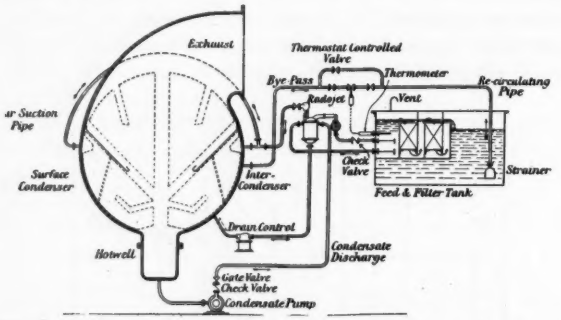


FIG. 3. TYPICAL ARRANGEMENT OF AN AIR EJECTOR WITH INTER CONDENSER OF THE RADOJET TYPE FOR AN OPEN FEED WATER SYSTEM

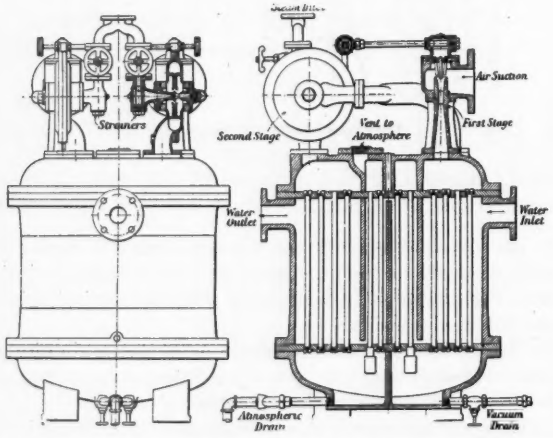


FIG. 4. UNIT IN WHICH THE INTER AND AFTER-CONDENSER IS COMBINED INTO ONE SHELL

The following conclusions may be drawn from these curves: 1. From 0.2 to about 5½ in. absolute the ejector with inter-condenser has considerably larger air handling capacity per pound of live steam supplied than the two-stage ejector without inter-condenser or the single-stage ejector. 2. For absolute pressures of 5½ in. and higher the second stage of the ejector without inter-condenser handles more air with less live steam than the inter-condenser ejector. Hence, for absolute pressures of 5 in. and more, the single-stage type ejector should be used. 3. Due to the fact that the air-handling capacity of the second stage of an ejector with inter-condenser is small, the time required for evacuation of the condensing plant will be greater. If rapid evacuation is desired, an additional single-stage ejector will have to be supplied for this purpose. The principal factors controlling the performance of an air ejector with inter-condenser are: (a) Condition of steam supplied. (b) Back pressure at the discharge. (c) The condition of the air handled. (d) The inlet temperature and quantity of circulating water. (e) Cooling surface of inter-condenser.

A typical arrangement of an air ejector with inter-condenser of the Radojet type for an open feed-water system is shown diagrammatically in Fig. 3. The condensate from the main condenser is used as circulating water in the inter-condenser. During periods of insufficient supply of condensate when starting or maneuvering a thermostatically operated valve opens and re-circulates condensate from the feed tank into the main condenser, wherein it is cooled by falling over the tubes and returned through the inter-condenser into the feed tank.

In some installations the water side of the inter-condenser is divided into two sections, each of which has its own water supply. One receives condensate from the main condenser and the other cold fresh or salt water from another source. The cold water supply is thermostatically controlled by the temperature of the condensate leaving the inter-condenser.

A further development has been made by combining the inter- and after-condenser in one shell and thereby

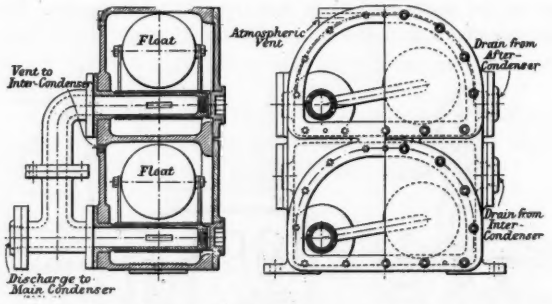


FIG. 5. DUPLEX DRAIN CONTROL

creating a compact and complete unit which entirely eliminates the absorption of air and non-condensable gases by the condensate when returning practically the total heat contained in the steam for extracting the air and vapors. Such a unit is illustrated in Fig. 4.

It will be seen that the second stage is arranged on top of the condenser shell and discharges into the after-condenser section which forms part of the whole unit. The steam issued from the second stage is condensed therein, while the air and non-condensable gases escape through a vent to the atmosphere.

A cold pass section is provided for the inter-condenser only. The after-condenser does not require a cold pass section because the temperature of the condensate leaving the after-condenser may reach 180 deg. F. or more without impairing the performance of the second stage of the ejector.

The water inlet to the cold pass section may be controlled manually or automatically by a thermostatically operated valve. If a cold pass section is not provided, a thermostatically controlled re-circulating system has to be installed.

The condensed steam from the first and second stage is returned into the main condenser by a duplex drain control as shown in Fig. 5. This consists of two separate compartments. The upper one is the atmospheric drain, the lower one the vacuum drain. The first receives the condensate from the after-condenser, the latter from the inter-condenser. Float controlled sleeve valves regulate the flow

of the condensate, which is returned into the main condenser by the prevailing pressure difference.

Vacuum Augmenter

Another development which should be recorded is that of the low-pressure steam-operated vacuum augmenter. The vacuum augmenter was invented by Sir Charles A. Parsons in 1903 and has since that time been applied in connection with wet air pumps of all types for the purpose of improving the vacuum created by the latter. High-pressure live steam was used as motive fluid in the augmenter, and hardly any changes in its design had been made since its invention until 1917, when, due to the incentive of Mr. John Metten, several augmenters of the Radojet type operated by exhaust steam of 3 to 5 lb. gage pressure were developed and successfully installed and operated in connection with twin-beam air pumps on a number of torpedo-boat destroyers. It was found that, for the same ratio of compression and when handling the same amount of air, this new type of low-pressure Radojet augmenter required of exhaust steam only about 25 per cent of the quantity of live steam used by the Parsons augmenter.

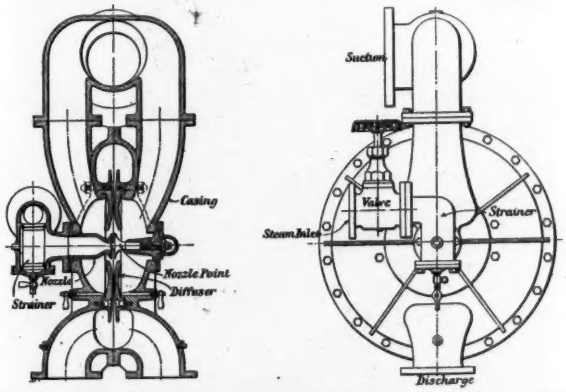


FIG. 6. LOW PRESSURE AUGMENTER OF THE RADOJET TYPE

A low-pressure augmenter of the Radojet type is illustrated in Fig. 6, and its arrangement in connection with a twin-beam air pump is diagrammatically shown in Fig. 7. In this arrangement the heat from the exhaust steam, used for the operation of the augmenter, is returned to the boiler by circulating the condensate through the augmenter condenser. The latter is of special design and is provided with a separate cold pass through which circulating water is flowing when there is not enough condensate available from the main condenser. The cold water supply is regulated thermostatically or manually. The application of the low-pressure augmenter improves the vacuum from 1½ to 2 in. over that obtained by the twinplex or twin-beam air pump.

For the removal of the condensate from high vacuum condensers turbine driven pumps of the centrifugal type are employed. If the total head, including the head due to the vacuum, exceeds 80 ft., two-stage type centrifugal pumps have to be used. There has been little recent improvement in circulating pumps for condenser service, due to the fact that pumps of the centrifugal type have reached a stage of development which is very near to the practical limits of high efficiency.

Development in the design of surface condensers has been confined to condensers used in stationary power plants and has been along the lines of increasing heat transfer and vacuum, deaeration of the condensate, highest possible condensate temperature, equal steam distribution and minimum pressure drop between exhaust opening and air pump suction.

In stationary power plants an absolute pressure of 1.3 in. with 70 deg. circulating water inlet temperature and a condensate temperature of 87 deg. F. corresponding to the absolute pressure at the exhaust inlet are being obtained. This is accomplished by proper spacing of the tubes and providing lanes leading exhaust steam to the

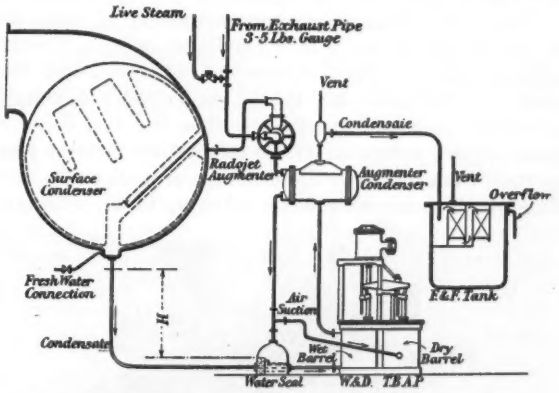


FIG. 7. AUGMENTER INSTALLED IN CONNECTION WITH A TWIN-BEAM AIR PUMP

bottom of the condenser for heating the condensate and assisting in its deaeration. Equal steam distribution is obtained by providing several air pump suctions, which also reduce the pressure drop and prevent inactive tube surface. There are a number of different tube sheet layouts in use which all embody in various forms the developments cited above.

Design of marine condensers does not show any of these developments, which may be due to the fact that the number of marine condensers built during the last five years has been small, for reasons well known. The gain in economy resulting from a higher vacuum, higher condensate temperature and less steam used for operating the condenser auxiliaries will in a short time pay for the higher price of a well-designed condenser installation. The application of the old rule of thumb: "So many square feet of cooling surface and so many inches diameter of air pump per horsepower," is a thing of the past.

Science has helped in the development of the design of condensers, their auxiliaries and their installation and has thereby created a special branch of engineering, which should be called upon by marine engineers and shipbuilders when considering new installations.

For the fiscal year of 1925, a net balance of $277,115 is shown by the Central Maine Power Co., according to Walter S. Wyman, president. Gross income was $4,156,478; depreciation accrued and actual and maintenance expenditures were $642,033, other operating expenses $1,486,585, interest and guaranteed dividends of subsidiaries $977,806 and dividends paid on preferred stock $700,692. Mr. Wyman states that if spring freshets do not interfere with the work, the power project at Gulf Island above Lewiston, Me., will be finished at a cost substantially less than the estimate.

Dutch Oil Engine Design

HOT BULB TYPE ENGINE USES LOW COMPRESSION AND AIRLESS INJECTOR. BY H. F. BIRNIE

IN AMSTERDAM, Holland, the Kromhout Co. has developed an oil engine which belongs to the medium-pressure type, using a so-called hot-bulb to insure the ignition of the fuel charge. Instead of depending entirely on the heat generated by the compression, the radiation of a partly cooled combustion chamber provides the necessary heat to ignite the fuel sprayed by the injection nozzle.

Hot bulb engines use a low compression of about 200 to 220 lb. per sq. in. with a maximum burning pressure of 250 to 270 lb. For a certain class of service and especially for small units, this type of engine offers indubitable advantages in maintenance costs. The fact that these engines require preheating of the combustion chamber when starting from cold is no disadvantage in itself as the short time used for this operation is taken up in any oil engine

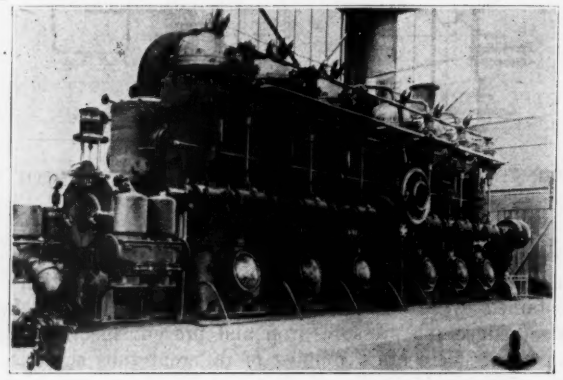


FIG. 1. THIS 6-CYLINDER DUTCH OIL ENGINE DEVELOPS 500 BREAK HP. AT 225 R.P.M.

to open the different water, lubricating and fuel oil connections. Generally hot bulb engines are of the two-cycle type with an airless fuel injection. Solid injection, as used on these engines, does not create the high fuel pressures used in the solid injection Diesels with high mean effective pressures. In comparison, the combustible jet is but roughly atomized, thus permitting the use of larger nozzle holes and eliminating careful straining of the combustible.

KROMHOUT ENGINE IS USED FOR MARINE WORK

Some years ago these engines were generally manufactured in small units but recently have increased in power range. The engine shown in Fig. 1, constructed by the Kromhout Co., is a 6-cylinder unit giving 500 brake hp. at 225 r.p.m. Like most designs, the engines developed by this company present some characteristic features as well as interesting refinements. Each cylinder unit is separately bolted to the bedplate and the camshaft driven from the camshaft by spur gears controls the individual starting valves and fuel pumps. The big maneuvering wheel in the center is used to start or reverse the engine, the small handwheel controlling the amount of fuel delivered by the pumps. The lever above the maneuvering wheel relieves the compression of all the cylinders at the same time. The bilge, water circulation, oil and fuel pumps are all located together at the front end of the engine.

Besides the individual silencers, Fig. 2 shows the burners used to heat up the hot bulbs in the combustion chamber when starting the engine from cold. The auxiliary compressor gives the necessary air for starting and maneuvering purposes while the separate lubricator takes care of the oiling of the compressor and the pumps. As usual on marine installations each cylinder has a safety relief valve. The compression relief valves located at the front of the engine are made integral with the starting valves. It should be noted that the bilge and the water circulating

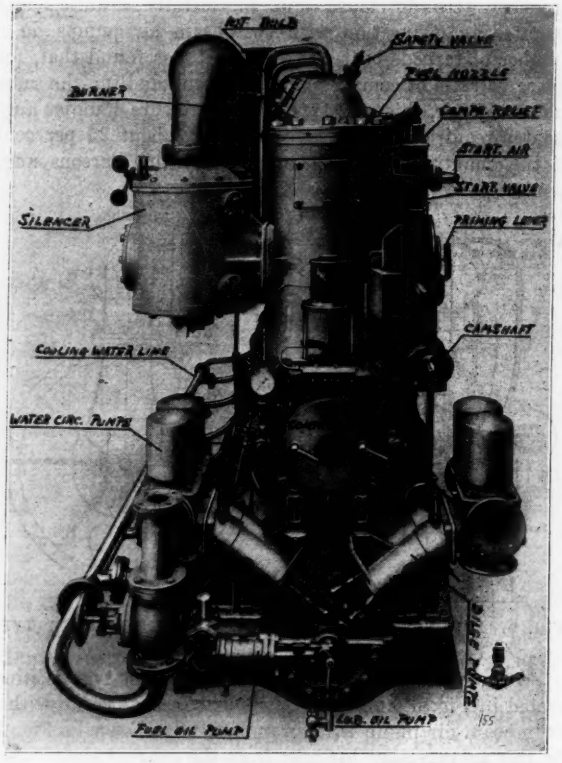


FIG. 2. END VIEW OF ENGINE SHOWS DETAILS OF OPERATING EQUIPMENT

pumps have safety valves, so as to prevent damage through careless closing of all the delivery valves. The cooling water for the engine enters at the lowest part of the cylinder and passes to the individual silencers after reaching the highest point in the combustion chamber.

Air scavenging arrangements are of the usual design, the air charge passing from the crankcase to the cylinder through a passage at the back of the engine and ports in the liners. The bedplate is in 2 sections bolted together and the short frames, which carry the air-inlet valves in both front and rear, are bolted to the cylinders. The liner is cast integral with the cylinder and the cylinder head is made in two distinct pieces, the inner one taking the combustion pressure and the outer one acting as cooling water jacket. The counter-weighed crankshaft rests on babbited main bearing shells, the latter not being provided in the bearing caps which have the babbit directly poured into the casting. The crankpins are lubricated by means of oil

slings. The camshaft which runs along the whole engine length is, during the maneuvres, simply shifted back and forth. For each cylinder there is but one starting and one fuel pump driving cam, as the profiles for the maneuvring motions are connected by a taper, thereby doing away with the necessity of lifting the rollers from the cams when moving the camshaft.

Airless Injection Is Used

Fuel is injected in the combustion chamber without the aid of compressed air, since the fuel pumps are directly driven by the camshaft through rollers which are in continuous contact with the cams except when cutting out a

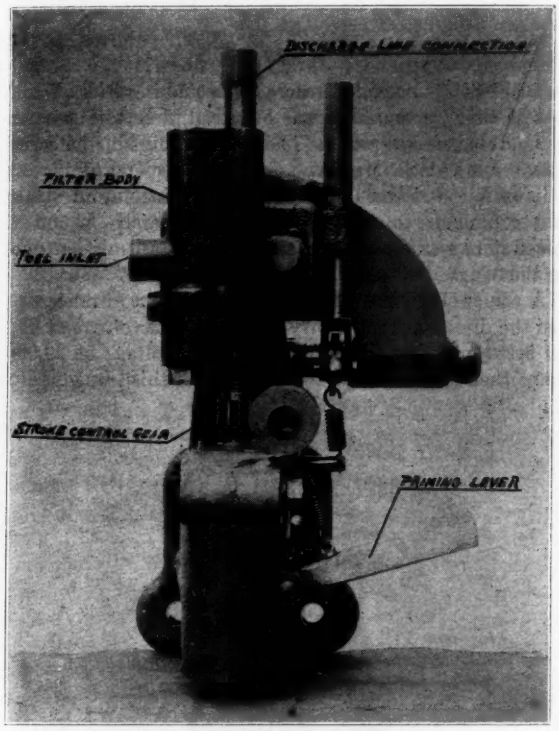


FIG. 3. THIS IS THE FUEL PUMP USED ON THE KROMHOUT ENGINES

certain cylinder by means of the priming levers shown in Figs. 1 and 2. The whole combustible is brought to the upper part of the pump and passes to the delivery space through a hollow plunger and drillings made in it. The suction valve of the fuel pump seats on top of the plunger itself and the discharge valve is located in the discharge pipe connection shown in Fig. 3. The pump has no by-pass valve, but the amount of fuel delivered to the nozzle is varied by changing the stroke of the plunger. This is obtained by increasing or decreasing the distance between the pump-roller guide and the crosshead pin by means of a gear operated by a rack. This rack is under hand control, as on all variable speed engines, but a governor driven from the camshaft limits the maximum r.p.m. and prevents racing of the engine. Figure 4 shows the two designs of fuel nozzles used on the Kromhout engine, one for the crude oils, the other for the tar oils and differing only by the shape of the whirler.

One of the characteristic features of the Kromhout engine is embodied in the piston pin design shown in Fig. 5. This arrangement does away with direct lubrication and only relies on the oil splashed in the crankcase. The usual gliding friction between pin and bearing is replaced by a rolling friction between a hardened flat steel bearing plate and a hardened steel piston pin. The latter is securely fixed in the piston body by a setscrew and a key. The tappet screw on top of the connecting rod eye is also made of hardened steel, and a small clearance separates it from the piston pin. As the engine is of the two-cycle

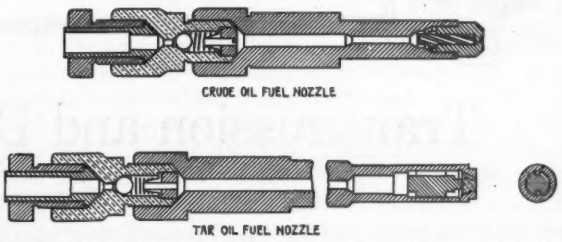


FIG. 4. THESE ARE FUEL NOZZLES FOR CRUDE AND TAR OILS

type, there is always a downward pressure on the piston top and the piston pin will never leave the surface of the hardened plate. The latter will thus rock back and forth on the surface of the piston pin, while the connecting rod follows the motions of the crankshaft. This rolling movement would, of course, be transformed to gliding friction

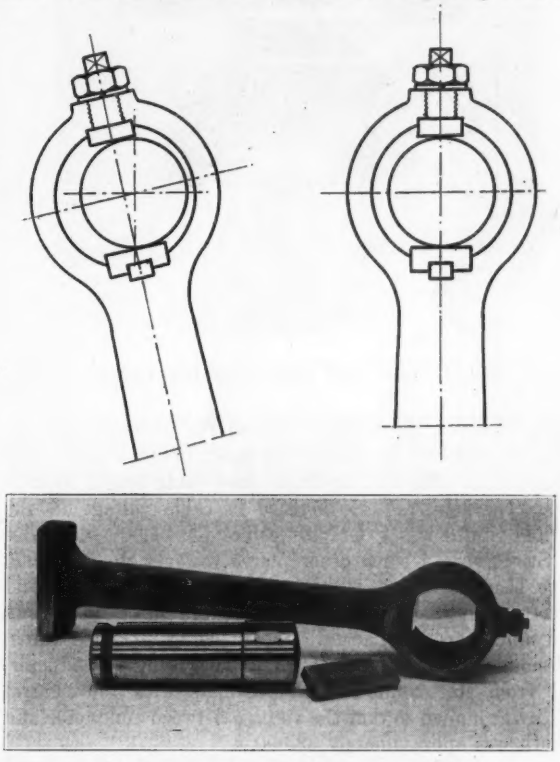
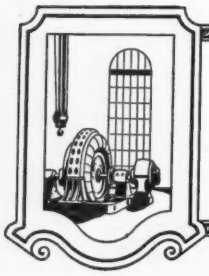


FIG. 5. PISTON PIN DESIGN REDUCES FRICTION BY ROLLING ACTION ON HARD STEEL PLATE

should the clearance between the tappet screw and the piston pin not be provided.

In the Kromhout engine the starting system follows a conventional cycle, the six-cylinder engine starting on all cylinders at first and the fuel being cut in gradually on those pairs of cylinders from which the starting air has been cut off. This sequence of operation is obtained by means of the big handwheel in the center of the installation and by appropriate contours on the cams.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Transmission and Distribution Lines---II

VOLTAGES EMPLOYED IN UNITED STATES AND EUROPE. TYPES AND DESIGN OF INSULATORS AND METHODS OF MOUNTING. BY STEPHEN Q. HAYES*

IN THE UNITED STATES, until comparatively recent years, there were very few underground cables operated at a higher voltage than approximately 13,200 v. and in most cases three-conductor cables were employed. In late years, however, the voltage utilized for underground distribution has been gradually increased, in some cases using 3-conductor cable and in other cases using single conductors. The first radical increase in cable voltage in the United States was to employ cables for 25,000 v. service in St. Paul. In some other places voltages up to 33,000 have been used and within the last year the Cleveland Electric Illuminating Company made a most interesting and much successful installation utilizing 66,000-v. transmission employing underground cable, single conductor, fed from star connected transformers with the neutral solidly grounded so that the voltage between conductor and sheath was approximately 38,000 v.

FIG. 1. TWO PART PORCELAIN INSULATOR

A somewhat similar installation, operating at 40,000 v., three phase, is contemplated for another city in the midwest.

THURY DIRECT CURRENT SYSTEM USED IN EUROPE

In Europe the "Thury direct current series system" has been employed in a few locations for a number of years. One of the earliest of these installations was a transmission from St. Maurice, Switzerland, to Lausanne, utilizing approximately 25,000 v. direct current, 100 amp., obtained from 10—2500-v. d.c. generators connected in series. While most of this transmission was overhead, a certain portion was operated underground. The middle point of the series of generators at St. Maurice and the corresponding motors at Lausanne was grounded so that the insulation strain from conductor to sheath was approximately 12,500 v. This system was replaced by three-phase transmission during the War.

A somewhat longer transmission to Lyons, France utilized the direct current Thury system with a voltage of 60,000 between the main conductors and a voltage of 30,000 from either conductor to ground. Most of this transmission was overhead but through the city of Lyons underground cable was employed. This Thury direct current series system supplying power to Lyons was to have its voltage increased to approximately 110,000 v. by putting in additional generating stations in series with those in service. With the neutral point solidly grounded on the series of generators at one end and the series of motors at the other end, the voltage from any conductor to ground would be limited to 55,000 v., d.c. This change from 60,000 to 110,000 v. will probably never be made as three-phase transmission will be employed.

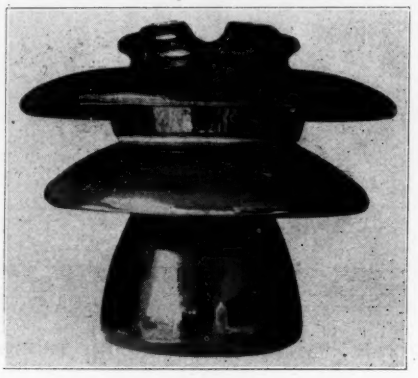


FIG. 2. THREE PART PORCELAIN INSULATOR

In Paris the transmission and distribution from the large turbo-generator installation at Gennevilliers is by means of 60,000-v. underground cables to various substations.

The usual overhead transmission and distribution systems on an a.c. installation utilizing high voltage employs bare conductors in nearly every case, these conductors being spaced suitable distances apart and being supported on proper insulators, usually of porcelain.

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Attempts at Standardization

While various voltages have been employed in different parts of the world for power transmission service, there is a general tendency to reduce to a minimum the different voltage ratings and to standardize, if possible, on multiples of eleven, such as 11, 22, 33, 44, 55, 66, 77, 88, 110, 132, 154, 187, 220 kv. Many of the interurban transmission systems in the middle west have utilized 22 or 33 kv. and a number of the shorter power transmission have utilized 44 kv. In the United States there are comparatively few transmissions at 55 or 77 kv., although this voltage is frequently utilized in Japan and in various parts of Europe. 66 kv. is fairly common and 88 kv. rather rare. While there were a number of transmissions at approximately 100 kv., 110 kv. is more frequently employed. A few transmissions exist at 120 kv. and a comparatively large number at 132 kv., this being employed for interlinking many of the transmission systems throughout the middle west. In Michigan, 140 kv. has been used and in California, 150 kv. In Japan, as well as in France, 154 kv. has been selected as the super power interconnection voltage. In California, 220 kv. has been adopted by the Southern California Edison Company, and the Pacific Gas & Electric Company, these installations operating with the neutral solidly grounded and using equipment such as would normally be employed for a 187 kv. ungrounded system.

Insulator Design

For the support of the overhead conductors, suitable insulators must be provided. While glass insulators were used to a certain extent up to about 22 kv., porcelain insulators are now almost universal for this service.

For the more moderate voltages, pin type insulators are employed, while for the higher voltages, namely 66 kv. and above, it is customary to utilize disc insulators with the transmission wire hung from the bottom disc. For inside service various designs of porcelain have been employed in order to obtain mechanical strength, high flashover, and other desirable characteristics.

The porcelain used is a vitreous homogeneous mixture of clay flint and feldspar. These raw materials are finely ground, accurately proportioned and intimately mixed in a fluid state. The mixed material is then reduced to a plastic state by filtering under pressure.

Most of the insulators used for line service are made by the wet process. Blocks of the plastic material about the consistency of putty are worked into the desired shape and placed in plaster of paris molds. The surface not in contact with the mold is then worked into the desired shape by machine forming or pressing. The piece is removed from the mold after it is partly dried and is stiff enough to handle. The surface which was in contact with the mold during the pressing operation is then finished to accurate dimensions. The body is then thoroughly dried and glazed with a material that fuses into a glass at the firing temperature of the porcelain.

Pin type porcelain insulators for voltages above 6600 are usually made by the wet process and are generally in two pieces, like Fig. 1, for voltages up to about 20,000 and in three or four pieces, like Fig. 2, for higher voltages up to about 70,000. The multi petticoat porcelain insulator usually has its parts burned separately and cemented together after having been tested and inspected. This insures uniformity of production and ample reliability.

Porcelain pin type insulators are made in a number of sizes and shapes for the different voltages ranging up to about 18 in. in diameter and about 14 in. in height, with two to four petticoats provided to facilitate shedding the rain and to give a long dry arc over path. These insulators are generally made to be mounted on 1⅜-in. wooden pins. When steel pins are to be used a thimble threaded to fit the pin is cemented into the procelain. Grooves are provided on top and side for the line wire, tie wire and clamps.

The suspension type insulator, Fig. 3, frequently spoken of as the disc type insulator, was developed at the time when voltages were increased above 50,000 because of the excessive weight of pin insulators for such voltage and the difficulty of securing proper mechanical strength in the pins. By using the disc type insulator it is possible to have ample clearance from the supporting structure and ample flashover value. The suspension insulators are made of porcelain by the wet process and are made of separate disc units which are assembled in series strings, each unit being provided with suitable means for attaching to other units. In most cases a galvanized iron cap is cemented on the top of the insulator and a galvanized pin in the bottom.

FIG. 3. STANDARD SUSPENSION INSULATOR

The top unit is suspended from the pole or tower crossarm and the conductor is secured to the bottom unit. The number of units used in a string is not standard but depends on climatic conditions, line construction and the personal ideas of the responsible engineers. For 150,000 v. service, 9 or 10 ten-inch disc insulators are usually considered sufficient, while for 220,000 v., 13 or 14 are normally supplied. The freedom of the string to swing under side strain necessitates proper allowance in the length of the arm for such motion due to the wind pressure and the angles in the line.

The diameter of these discs varies from 6 to 10 inches or more, although the 10 inch size is considered standard by most manufacturers for normal conditions.

Poles and Towers

As a mechanical support for the porcelain insulators, poles or towers are employed with crossarms and supporting members of suitable design. Wooden poles have been used to a large extent for electric power distribution, electric railways and power transmission lines because of their adaptability to such service. As a rule, they have the advantages of suitable insulating qualities, durability and cost. In the eastern part of the United States chestnut poles are common. In the central states, northern white

cedar is used, and farther west, western cedar and red wood probably outnumber other materials. Other kinds of timber locally available, such as cyprus and pine, have been used in the southern states.

Poles for this service should be of such material as can be counted on for fairly long life in contact with the ground. The poles should be straight, of relatively small size and little taper, minimum weight and reasonably soft, so that the spikes of a climber may enter readily, while having strength to support considerable weight. To decrease the decay and the weakening of the poles at the ground line they are commonly treated with creosote or other wood preservative. Such treatment in many cases almost doubles the life of the poles made of the common timbers.

Wooden poles are commonly classified as to length in steps of 5 ft., such as 20, 25, etc. and by top circumferences, such as 18, 22, 25-in. tops. 30, 35, and 40-ft. length poles are those normally used. Wooden poles are roofed by bevelling so that the water will drain off and not rot the top.

In certain places, concrete poles, usually steel reinforced, have been installed. Such poles are of the greatest value where the life of wooden poles is unduly shortened by local conditions. Concrete poles have been made in lengths as high as 75 ft. A recent design of concrete pole is made with a hollow core in a centrifugal molding machine.

For lines, crossing rivers or railways, at elevations greater than can be taken care of by the normal wooden poles, steel poles of lattice construction are frequently employed. These steel poles are usually set in concrete and they require less ground space than a transmission tower and are used where a tower could not readily be employed. One particular type of pole is made by cutting and expanding the web of an eye beam by special machinery, making what is termed an expanded steel pole. One end is made wider and is used as the base of the pole. A lattice type pole built up of structural steel shapes with the lattice work riveted, bolted or welded in place is some times used for points in railway systems where heavy strains occur, as on curves or at places involving large spans.

Most of the important high tension transmission lines are installed on steel towers and these are used where the size and voltage of the line and the importance of reliability of service demand the highest type of construction.

The term "tower" as applied to the supports for transmission and distribution circuits is usually applied to a structure of fabricated steel having a broad base and a height of 35 to 50 ft. or more, while the smaller fabricated structures with small bases and lesser heights are usually spoken of as "lattice poles."

Steel towers are most suitable for the support of transmission line circuits because with their use spans may be lengthened and greater security of strain against wind and ice obtained. They must be designed for the loads they are to carry with a reasonable factor of safety. As a rule, the most economical use of the metal is obtained by tower designs having bases from 10 to 20 ft. square. The height of the tower must be sufficient to give suitable clearance above ground for the transmission wire at the lowest point in the span. With conductors arranged above each other in a vertical plane, the height of the tower is fixed by the clearance above ground at the bottom of the span of the lowest conductor. In rough country, where tower sites may be chosen on elevations, clearance above ground may often be secured without providing extra height of the tower to allow for the sag of conductors.

In level country a flexible type of tower may be found economical and adequate. Such towers are frequently made in the form of an "A" frame, which is rigid against transverse stresses and somewhat more flexible along the line. With this type of construction it is usual to place rigid towers at intervals of about three or four thousand feet to limit the line trouble in case of a break. With the flexible type of tower a steel strand cable, used as a ground wire at the top of the tower, acts as a longitudinal guy.

Towers for transmission purposes should be well galvanized and painted and the foundations of the tower lines must be of such dimensions as to prevent overturning. To insure a reasonable life concrete fittings from 4 to 6 ft. deep are usually provided in each corner of the tower. This concrete fitting includes a steel connection to which the base of the tower is bolted and the whole is brought sufficiently above the surface to keep it above the moisture line.

The spacing of poles or towers in transmission line or distribution service depends somewhat on the local characteristics and for very high voltage it is customary to utilize the maximum feasible tower spacing so as to reduce to a minimum the number of insulating supports. Some of the more recent transmission systems use comparatively high towers spaced about four to the mile, while at river crossings or in the mountainous districts, much longer spans are frequently found.

Modernizing a Swiss Hydro-Electric Power Station

THE SOCIETE des Usines Electriques d'Olten-Aarburg recently decided to modernize its hydro-electric power station at Ruppoldingen on the Aar, which has been in operation since 1896, in order to take advantage of the latest progress in lowhead turbine design and at the same time to change over from 2-phase 40-cycle, to three-phase 50-cycle current. The old plant consisted of 10 Jonval-type axial turbines, developing 300 hp. at 28.5 r.p.m. Four of the turbines were coupled direct to the generators, while the six others were arranged to work in pairs and operate by bevel gearing 300-hp. horizontal shaft alternators. The contract for the reconstruction work was entrusted to the Societe Motor Columbs of Baden, as regards the electrical equipment and to the Societe des Ateliers des Charmilles, of Geneva as to the turbines. One of the conditions demanded that the new plant should require no alterations in the foundations and underground construction of the power station, a stipulation which rendered it impossible to employ for the new turbines high-efficiency suction pipes such as the modern screw type turbine demands. After carrying out special experiments to meet the conditions imposed, the Charmilles Co. have supplied nine vertical shaft turbines which while utilizing the existing water conducting and discharging passages develop 1000 hp. at 94 r.p.m. as against the 300 hp. of the old machines. The first three of the new sets of turbines and generators have been in operation for some time, having passed the reception tests successfully. A feature of the plant is that the different sets are arranged to work in parallel, the turbines not being provided with any automatic speed regulating device.

Power Flow in Electrical Machines

DR. SLEPIAN EMPHASIZES THE FACT THAT IN ELECTRICAL CIRCUITS POWER FLOWS NOT IN THE CONDUCTORS BUT IN THE SPACE AROUND THEM

AT A JOINT meeting of the Chicago Section of the American Institute of Electrical Engineers and the Western Society of Engineers, January 11, Dr. J. Slepian* delivered an exceedingly interesting paper on the flow of power in electric circuits and machines. Dr. Slepian's paper, although of a rather abstruse nature, dealing as it did with a new conception regarding the flow of energy in an electric circuit, was characterized by this young engineer's usual clearness and simplicity of exposition. Dr. Slepian possesses the rare ability to explain highly complex conceptions in an interesting way.

In discussing the flow of power in electrical circuits, Dr. Slepian considered that the power flows not in the copper conductors, as we ordinarily conceive it to flow, but in the space around them. This is somewhat different from the usual conception of electric power flow and since in some ways it may seem to oppose the accepted theory, the question arises, which is true? If this new conception is true, is the old one wrong? Is the new one untrue? Or can they both be true?

Before discussing the subject of power flow from this new viewpoint, Dr. Slepian deemed it necessary to first discuss briefly the question of the ultimate nature of truth. In other words, is there such a thing as an absolute truth? Can we say, conclusively, this thing is true, therefore, that thing is *not* true? Does the fact that one conception is true prevent another conception of the same thing from being equally true?

From a consideration of modern physics and of relativity we must conclude that two different conceptions of the same thing may be both true. A hundred years ago we would not have reasoned in this way but so many of our old time notions have been shattered by the new physics that we are beginning to look at things in a different manner. Our most fundamental conceptions—those of the absoluteness of space and time—have been shown incorrect. Space and time, instead of being absolute, are shown to be purely relative conceptions. The space and time for one observer is not the space and time for another observer, yet so far as each observer's conception is concerned, both are true. Each observer employs his own conception of space and time to explain phenomena and if it explains these phenomena in a satisfactory manner, his conception may be said to be true, for him alone, however.

So, reasoned Dr. Slepian, we can conclude that there may be more than one truth regarding certain phenomena. There may, however, be degrees of truth; that is, one truth may be greater than another insofar as it is able to explain a greater number of conditions. From this standpoint, Dr. Slepian considered his theory of power flow to be more true than the existing theory, since his theory was able to explain satisfactorily a larger number of conditions.

Reverting for a moment to the modern physics, Dr. Slepian pointed out that in this new physics—relativity—we have introduced something new, something that our older physics did not contain, and that is, intelligence. In all of the explanations of the principle of relativity, we assume an observer endowed with certain reasoning powers. This is something not done in connection with our former notions regarding space, time and man.

So in explaining the new theory of power flow, Dr. Slepian proposed to employ some being endowed with intelligence. Most of us started our study of electrical engineering by the aid of hydraulic analogies, so here also he proposed to start with an hydraulic analogy. Consider the arrangement of pipes shown in Fig. 1 which, as will be evident, is analogous to the electric circuit of Fig. 2. The pump corresponds to the generator, the pipes to the wires and the water motor to the electrical load. The current i in the wire is represented in the hydraulic system by the amount of water flowing through the pipe and the voltage V acting on the electric circuit corresponds to the pressure produced by the pump. To obtain the amount of power in watts in the electrical circuit,

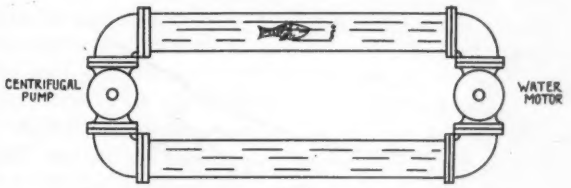

FIG. 1

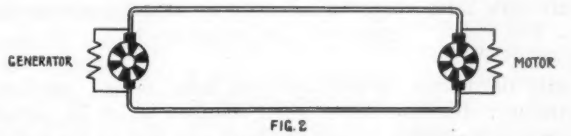

FIG. 2

FIG. 1. FISH IN PIPE SYSTEM IS ABLE TO DETERMINE WHETHER OR NOT POWER IS BEING TRANSMITTED

FIG. 2. SIMPLE ELECTRIC CIRCUIT FOR SHOWING TRANSMISSION OF ELECTRIC POWER

the voltage V is multiplied by the current i. In the pipe system the power flow is arrived at in the same way.

Now, let us assume a fish to be swimming in the pipe, and further assume that it is an intelligent fish—one endowed with certain reasoning powers. Is it possible for this fish, swimming in the pipe to find out whether or not power is being transmitted? Let us see. As the current carries him along, he notes various marks on the walls of the pipe and as they pass by at a uniform rate he realizes that the water must be in motion; he knows there is a current. Now, what about pressure—can he know that there is pressure in the pipe? Yes. Assuming that the fish is compressible, he is compressed and finds by measuring his body that he has become smaller in diameter or in circumference. So he reasons that the water surrounding him is under pressure. Since our fish is capable of knowing that both current and pressure exists in the pipe, he can, by multiplying the pressure by the current, determine the amount of power being transmitted.

Proceeding now to a consideration of the electric circuit shown in Fig. 2, let us see whether an intelligent being in the wire, an electron fish, for instance, could determine if power was flowing. This fish, like the fish

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in the water, is also capable of determining that there is current by noting his motion relative to the pipe. But unlike the water fish, he can have no knowledge of the potential acting on the circuit. Being inside of a metal conductor, he is entirely shielded from all lines of electric force and cannot be aware of them. Faraday long ago showed that if a man was placed in a metal cage or box and the box charged to any potential above that of the earth, he would not be cognizant of it. So, said Dr. Slepian, we find our electron fish at a decided disadvantage; he cannot form an idea of potential, therefore he cannot know that power is being transmitted.

Bird in Space Around Wire Knows Power Is Transmitted

Let us now consider a bird. Suppose a bird flying through the air comes close to the wires of a high potential transmission line. As he approaches the wires, the hairs on his feathers under the force of the electric field, suddenly rise and stand up on end. The bird feels this and coming to a stop says "Hello, this wire must be charged with electricity." At the very outset, then, this bird has the advantage over the electron fish. This bird, however,

FIG. 3. A BIRD FLYING CLOSE TO A HIGH POTENTIAL TRANSMISSION LINE FEELS THE EFFECT OF THE ELECTROSTATIC FIELD ON HIS FEATHERS

said the doctor, is an intelligent creature and has been trained. Hauling out a small compass which he carries around, he places it near the wire and noting the deflection, immediately knows that, in addition to the electric field about the wire, there is also a magnetic field and, therefore, a current in the wire.

It is apparent then that the bird in the space around the wire knows a great deal more about what is happening in the electric circuit than the electric fish in the wire. He knows that there are two fields of force about the wire; first, the electric field extending radially outward from the wire and, second, at right angles to the first but in the same plane, the magnetic field, the lines of which are concentric with the conductor. In Fig. 4 is shown a section through the two conductors of the circuit showing the two fields of force.

Use Made of Poynting's Vector

At this juncture, Dr. Slepian briefly discussed the application of Poynting's Vector to the solution of the problem. Poynting's law, named after the English scientist who discovered it some fifty years ago, is stated as follows: When a conductor carrying a current is in an electrostatic field, the transfer of energy takes place through the dielectric along paths which are the intersections of the equipotential surfaces of the electrostatic field with the equipotential surfaces of the electromagnetic field due to the current. From this law and from a study of Fig. 4 it is apparent that the energy transfer is in a direction parallel to the wire. The points of intersection of the two fields are represented by the black dots, hence, if any power is to be transmitted in accordance with Poynting's law, it will necessarily have to be in a direction parallel to the wire.

So our bird flying around in space is capable of determining that there is a transfer of energy along the wire; furthermore, by plotting the lines of force and integrating the entire field, he can calculate the magnitude of the energy flow.

Here we have a new conception—something entirely different from the commonly accepted theory. We have been accustomed to regard the power as being transmitted through the wire. Now, viewing the phenomena from a

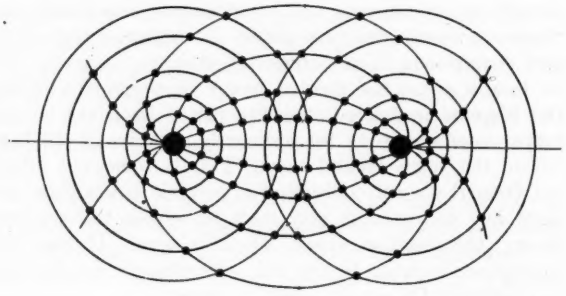

FIG. 4. DIAGRAM SHOWING THE ELECTROSTATIC AND MAGNETIC FIELDS SURROUNDING TWO WIRES CARRYING AN ELECTRIC CURRENT. THE SMALL BLACK DOTS SHOW POINTS OF INTERSECTION OF EQUIPOTENTIAL SURFACES OF THE ELECTROMAGNETIC AND ELECTROSTATIC FIELDS

different standpoint, we find that all the energy or at least practically all of the energy exists in the space between the wires.

The remaining portion of Dr. Slepian's talk was concerned with the application of this conception to the interpretation of various conditions which arise in electric circuits.

In an investigation being conducted at the Pittsburgh, Pa., experiment station of the Bureau of Mines, Department of Commerce, an effort is being made to determine whether the character of the precipitates forming in boilers may be made to assume a form in which they do not attach themselves to the walls; and if the material in the boiler wall exercises any influence. Data have been obtained on the non-condensible gases which are carried off in the steam, and the correct relationships to be maintained when carbonate becomes unstable and phosphate must be used in boiler water conditioning. The use of phosphate may form objectionable deposits. This condition is being looked into. Further, indicators used in titrating boiler waters do not necessarily represent the true phosphate or carbonate concentration. Means of controlling this indication are being investigated. Conditions which may bear on wet steam are being watched in the hope that definite information may be acquired on the factors influential in wet steam development and thereby control be obtained over them.

The New England Power Co. of Worcester, Mass., is to erect an additional power plant at Rowe, Mass., from private plans, which will cost about $35,000. The Sherman Power Construction Co. has the contract. The building will be of concrete and steel, one story.

Recent Developments at Colfax Station*

Historical Sketch of Equipment in This Plant of Duquesne Light Co. and Data on Performance Results. By Charles W. E. Clarke†

COLFAX STATION of the Duquesne Light Co. which serves the district in and around Pittsburgh, Pa., started its first unit in December, 1920. This and the second unit started in October, 1922, are practically duplicate, but the third unit is materially different.

In the first unit is included a 60,000-kw., 3-element turbo-generator, condenser with 100,000 sq. ft. surface in 4 shells and having Le Blanc air pumps, 7 cross-drum boilers, 51 by 18 tubes with superimposed superheater, fired by 17-retort, 22-tuyere underfeed stokers with clinker grinders, operating at 275 lb. per sq. in. and 600 deg. F. The auxiliary power system is a 2000-kw. house turbine exhausting to atmospheric condensers or feed-water heaters and a 750-kw. synchronous induction motor-generator set, both feeding house busses.

The second unit varied only in having 6 boilers, 20 tubes high, superheaters of interdeck type and steam-jet air pumps. Extensive coal-handling and storage equipment was provided, and several boilers have been equipped with air preheaters.

Latest Unit Is Different

When the third unit was decided on, higher pressures and temperatures, pulverized fuel, air preheating, steam reheating and multi-stage bleeding were discussed. Conditions finally adopted were 275-lb. pressure, 650-deg. F., pulverized fuel, 4-stage bleeding with an auxiliary generator on the main turbine shaft for house service and 2 35,000-kw. multiple-exhaust turbines in place of a single larger one. Also only 5 boilers were added for pulverized fuel, a sixth for stoker-firing being put into vacant space in the existing boiler house. The new boilers have 47 by 20 24-ft. tubes giving 27,680 sq. ft. of heating surface. Fourteen burners are used per boiler in two batteries of seven each, the drums being set 5 ft. higher to give more combustion space than in the older units. Preheater ducts are to be carried down the side of the boiler walls.

Two 6-ft. pulverizing mills are installed for each boiler, on the top floor directly under the raw-coal bunker and above the aisle between the two rows of boilers. Mills and the separators above them are walled off to isolate them from the rest of the boiler house. Bunkers of 35-t. capacity for the pulverized coal are in front of each boiler above the drum lines, feeding direct to the burners. Bunkers are supplied by a duplicate set of screw conveyors, cross-connected so that any bunker may be fed from any set of mills.

Plate air preheaters are located above the boilers, with fans in separate rooms connected so that air may be taken from inside or outside the boiler room. All are on the same level as the pulverizer mills.

Two boiler furnaces have hollow side and front walls, air cooled by air passing to the furnace and rear walls with plain-tube water screens. With CO_2 above 13 per cent, it is found that these furnace walls will slag and run. Three boilers have plain-tube rear walls, fin-tube side wall water screens and hollow front walls. They will carry considerably higher CO_2 without slagging.

All ash pits have water screens, hollow-lined, air-cooled bottoms and dump the ashes into sluices, running lengthwise of the boiler house and discharging into receiving pits whence ashes are taken by a clam-shell bucket into cars or trucks.

Auxiliaries Are Motor-Driven

All auxiliaries except the steam-jet air pumps are electrically driven from the house generators but have a "voltage chaser" which automatically throws them to the station bus or vice-versa in case of loss of voltage on either.

Condensate from the hot well flows through generator air coolers, transformers, turbine-bearing oil coolers and condensers for the steam-jet pumps, in the order given, to act as a cooling and condensing medium, the condensate gaining some 29 deg. F. under full load conditions. Steam for the bleeder heaters reduces the efficiency about as much as the losses reclaimed in condensate, but clean water is used and clogging by leaves and scum is avoided. Raw water can be used in emergency for cooling generators and transformers, but is not passed through the transformer coils which are cooled by heat exchange.

Boiler feed pumps are driven by 500-hp. variable-speed motors, the speed being varied from 1630 to 1800 r.p.m. by the Hagan automatic pressure regulator, using a balanced piston actuated by the difference between boiler feed and steam pressures. A rack on the piston rod turns a gear to operate a notching drum which in turn closes a circuit controlling a pilot motor to drive the main controller a given distance when a releasing device opens the pilot motor circuit. This operation is repeated until increased speed of the pump motor gives sufficient pressure to bring the regulators to rest.

Push-buttons labeled start, stop, fast, slow, automatic and manual are mounted on the control panel for operating the system.

In the additional intake, two rows of screens have been used, the front of 1½-in. mesh, the rear ⅜-in. mesh to take care of the heavy deposits of leaves in fall and spring.

Boiler Room Operation

From Mar., 1922, to July, 1924, the older units were run at an average of 170 per cent of rating and showed efficiency averaging 75.4 per cent. From July, 1924, to July, 1925, the average load was 157 per cent rating and average efficiency 79 per cent, varying from 77 to 81 per cent but with steady upward trend.

Unavailability has averaged 10 per cent for all boilers, due to cleaning, repairs and alterations. Over a period of 4½ yr., 43 tubes have been replaced, 36 for test purposes to determine cause and extent of corrosion; 4 due to cutting and 3 because of small cracks and holes.

Turbine Room Operation

With variations due to temporary operating conditions, the trend of average heat consumption per kilowatt hour for the station has been downward since 1922 but a marked reduction has been made since the third unit went into service in 1924, the average for the first 6 mo. of 1925 being about 17,750. At present precise deter-

*Abstract of paper read at the Annual Meeting of the A.S.M.E.

†Engineer with Dwight P. Robinson & Co.

mination of results from the third unit by itself cannot be made but tests show the heat rate at the boiler nozzle to be for full load 12,752 B.t.u. per net kw-hr. delivered; for ¾ load, 13,021 B.t.u.; for ½ load, 14,200 B.t.u. Full readings are given in the paper, the main conditions being, pressure 266 to 270 lb., temperature 566 to 598 deg., condenser vacuum 28.15 to 28.35 in., back pressure in exhaust 0.99 to 1.22 in. abs., hot well temperature 76 to 83 deg., discharge tem. from No. 4 heater 303 to 349 deg.

As to reliability, from Dec., 1920, to July, 1925, the first three-unit turbine has been available in whole or in part 93 per cent and as a complete unit 70 per cent of the time. Chief causes of outages have been blade and dummy rubbing, the rest being due to minor repairs and changes. From Oct., 1922, to July, 1925, the second turbine has been available wholly or partially for 85.5 per cent and as a complete unit 82 per cent of the time. Outage for repairs and alterations has been 7.5 per cent of the time, over half being for blade and dummy trouble. The third installation has been in service less than a year, the first unit of this being available 86 per cent of the time and the second 92 per cent.

Station Cost

Lowest cost per unit of output, including fixed as well as operating expenses, is the proper objective in power station design. Local conditions and difference in method of reporting doubtless explain part of the wide differences in costs, which vary from $70 to over $200 per kilowatt capacity. But capabilities of designers and builders are important factors in cost and details must be taken into account in making comparisons. Including power station, sea wall, intake and discharge tunnels, outside switching station, overhead costs, engineering and construction fees, the cost of Colfax Station at completion of the second unit was $116.51 per kw. for 120,000 kw. capacity. With the third unit added, the capacity is 190,000 kw. and cost per kw., $115.80 including building, foundations, reserve boilers and service equipment which are applicable to the fourth unit.

This fourth unit, which is under way, will be 80,000 kw., giving a total of 270,000 kw. at estimated cost of $107.50 per kw.

Division of costs is as follows for the 190,000-kw. capacity:

Building and foundations	20.1 per cent
Boiler plant	16.1 per cent
Turbine and generators	15.9 per cent
Switchboards, transformers, conduit and wiring	14.4 per cent
Piping	6.9 per cent
Condensers and auxiliaries	6.8 per cent
Draft system	4.9 per cent
Condensing water system	4.1 per cent
Auxiliary equipment	1.9 per cent
Service equipment	1.7 per cent
Station yard and tracks	1.7 per cent
Coal handling	1.3 per cent
Feed-water system	1.3 per cent
Sea wall and shore protection	0.9 per cent
Outdoor switching station	0.7 per cent
Machinery foundations	0.7 per cent
Preliminary operation of plant	0.6 per cent

Insufficient Data for Estimating Fuel Waste

Flue Gas Temperature, Soot on Tubes and Carbon in Ash Entirely Overlooked. By H. D. Fisher*

IN THE Nov. 15 issue, p. 1152, F. C. DeWeese cites an investigation of a poorly run boiler plant, and, while there are many plants undoubtedly as bad or worse, it is questionable whether all of Mr. DeWeese's conclusions necessarily follow from his observations.

Regarding the flue gas losses, it is not specified where the samples were taken, but this was presumably in the main flue of boiler uptakes. Low CO_2 here is not an infallible indication of poor efficiency unless the flue temperature is comparatively high, as often with good firing and reasonably tight boiler settings there is sufficient air leakage around flue necks, front doors and flue joints to greatly dilute the flue gas with cold air, giving low CO_2, but also low flue temperature, so that the actual flue gas losses are not excessive nor greater than for normal percentage of CO_2 and normal flue temperature.

The low average rating developed is not conclusive evidence either way, as it may be due to poor draft caused by excessive air leakage and low stack temperature or to poor firing and not utilizing a greater percentage of the air passing through the furnace for combustion.

Although the chimneys are short, their 48-ft. height should give about 0.24 in. draft at the boiler damper, since in practice the available draft from a chimney amounts to about 0.5 in. of water per hundred feet of height. With good firing and depending on the number and size of the boiler tube, there should be available in the fire box, ½ to ⅔ of this amount, which should be sufficient to give rates of combustion between 15 and 20 lb. per sq. ft. of grate per hr. In hand-firing practice it is customary to allow 1 sq. ft. of grate for each 5 hp., so that these 150-hp. boilers probably have about 30 sq. ft. of grate surface. As one-eighth the grate area is ample for stack area, the 6.6 sq. ft. is a generous provision.

Kent's formula for chimneys contains a considerable allowance for flue resistance and overloads, so that in simple cases of this kind a direct consideration of available draft and area allows of more detailed estimate of the possibilities of the equipment. Probably if the numerous leaks in the setting were fixed up the load could be carried on two boilers and by raising the rate of combustion to around 12 lb. per sq. ft. of grate per hr., better fires could be carried and more efficient results obtained. Increasing the height of chimneys when not necessary is, as has been found in oil burning installations, only a temptation to the fireman to operate with wasteful amounts of excess air.

Mr. DeWeese's method of calculating excess air is subject to considerable errors for low percentage of CO_2 when the fuel contains any material quantity of available hydrogen. The formula he uses is only applicable to an all-carbon fuel. For the average run of coals, the hydrogen requires about one-sixth as much oxygen for complete combustion as the carbon and with these constituents the excess air formula based on per cent CO_2 is:

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Percentage excess air $= 100 \times (20.9 - \frac{7CO_2}{6}) \div \frac{6.735\ CO_2}{6}$. By this formula 4 per cent CO_2 figures out to 354 per cent excess air instead of 417, as given by Mr. DeWeese.

It would also be interesting to know how Mr. DeWeese arrives at his figure of 1 per cent preventable loss for each 12.11 per cent excess air. No figure for flue gas temperature was given although this is vitally necessary for calculation of all heat losses. Based on the specific heat of air this would mean a flue temperature of 560 deg. F., which seems high with only 4 per cent CO_2 and 55 per cent rating.

The estimate of loss due to boiler scale also seems high. There has been much unfounded discussion of the enormous losses due to boiler scale, but it will usually be found due to scale on the fire side of the tubes rather than on the water side, in other words, to soot rather than scale. A report of the University of Illinois Experimental Station on "The Effect of Scale on the Transmission of Heat Through Locomotive Boiler Tubes" has been widely quoted in support of the scale evil, but the first series of tests, in which the startling results of losses up to 16 per cent of the fuel were obtained, were so irregular that almost anything can be proved from them. Scaled tubes showed greater heat transmission than clean tubes and individual clean tubes showed variations up to 4 per cent.

In the later series of tests where the experimenters had become more proficient in handling the apparatus, the results were much more regular and the differences shown between clean and scaled tubes were much smaller, being only about 2 to 4 per cent, which corresponds more nearly to operating experience. In boilers which are not being pushed to extremely high ratings, it is not an unusual experience to find $\frac{1}{16}$ in. scale in the tubes next to the fire and I have seen a boiler with 3-in. tubes operated at rating for several months with so much scale in tubes of the last pass that a ½-in. pipe would not pass through the tubes and in some of which it took 24 hr. to drill out the scale with a turbine. None of these tubes burned out, although theoretically no heat was being absorbed.

Consider the matter another way. If the scale prevents the absorption of heat from the flue gases and reduces the boiler efficiency, the heat loss must go somewhere and the only place is up the stack, resulting in higher flue temperature. No matter how poor the fireman, he must at times, even if only accidentally, get a good fire so that the CO_2 comes up around 9 per cent, that is, approximately 100 per cent of excess air. Under these conditions, the heat of the flue gas represents about 4 per cent of the heat of the coal for each 100 deg. F. rise in temperature, so that if a 16 per cent loss is taking place, due to scale preventing heat transmission through the tubes, the flue gas temperature must be about 400 deg. above the average flue gas temperature for clean boilers which is 450 to 500 deg. F., or 850 to 900 deg. F.

Now thermo-couple measurements have shown that for clean boiler tubes the tube is only about 10 deg. above the temperature of the water inside, which for 100 lb. gage is 338 deg., so that the clean tube would be at a temperature of 348 deg. F. with flue gas at 450 to 500 deg. F. Experimental evidence seems to show that the rate of heat transfer by convection increases only slightly at higher temperatures, so that with the same amount of heat transmitted to the scaled tube by the hotter flue gas, the temperature difference between gas and tube presumably still would be between 102 and 152 deg. F. while the tubes in the last pass would be at a temperature of about 748 deg. F. This is approaching the safe limit, which means that the tubes in the earlier passes of the boiler, where gas temperatures run up to 2000 to 2300 deg. F., would likely exceed it.

But as there is no wholesale burning out of tubes under these conditions, it seems more reasonable that the insulating qualities of the scale on the water side of the tubes has been considerably exaggerated and that when large losses and high flue temperatures are really found, it is largely due to soot on the fire side, which cuts down the transmission of heat into the tube and allows the water inside to keep the metal down to a normal temperature. Mr. DeWeese beyond a general recommendation at the end makes no mention of this matter of cleanliness of the fire side of the tubes, which requires more constant watchfulness than for scale on the water side.

Another point requiring constant watchfulness on the part of the chief is unconsumed coal and coke in the refuse. Mr. DeWeese made no mention of this important item of loss in his report. Improper grates, excessive shaking, careless cleaning of fires, failure to burn down properly, all cause considerable loss and when using a high ash coal with tendency to clinkering, this loss may be excessive. It is an excellent idea in a small hand fired plant to have the refuse dumped in some conspicuous place, so that if the fireman is letting too much coke get away from him, someone else will have a chance to notice it.

Mr. DeWeese's treatment of the whole combustion part of the problem is unfortunate, as the term "preventable loss due to incomplete combustion" refers to an insufficiency of air supply rather than an excess, as in this case. The curve, which was designated Fig. 2, showing relation between CO_2, furnace temperature, excess air and fuel loss means nothing, for the furnace temperatures are obviously theoretical temperatures of combustion which mean nothing in a boiler furnace where temperatures are affected in each individual case by rate of combustion and boiler surface directly accessible to radiant heat. Also, the relation of CO_2 to excess air is strictly correct only for a single ultimate analysis of coal and only approximately correct, that is, within usable limits, for a single class of fuel such as the coals from a single district. As already stated, fuel loss has no relation to CO_2 unless the flue gas temperature is stated as flue gas may be diluted indefinitely after leaving the boiler tubes with air at room temperature without affecting the fuel loss or efficiency of the boiler at all.

A minor point is that all losses are figured on the basis of an operation of 8760 hours per year. While many public service plants carry full steam pressure at all times, the average industrial plant has considerable periods, in some cases nights, in nearly all cases week ends, when steam pressure can be greatly reduced if fires are not entirely out. This should reduce the estimate of radiation and steam leakage losses and, if properly applied to the rate of coal consumption, would give a more accurate idea of the boiler rating developed and what should be expected in operating conditions.

Readymade remedies such as these applied regardless of their suitability to the troubles of the plant, often have discredited the work of careful and conscientious engineers. No man can make a perfunctory examination and diagnose the trouble—he may suggest remedies for the

more obvious points but it is up to the man in charge, usually the chief engineer, to keep after these and the smaller losses day by day. Only the chief can prevent the condition where the accumulation of losses causes the plant to slip down hill so far that only extraordinary effort and expenditure can bring it back. In return for this effort he should be provided with pay and working conditions proportional to his responsibilities.

In the case cited by Mr. DeWeese, the chief was responsible for the disposal of $35,000 worth of coal, besides other supplies. What fraction of this, compared with the savings a competent man could make, did or does his salary represent? Some comment should have been made as to the type of man in charge and the general sanitary conditions of the plant. Often this is as important as recommendations for changes in mechanical equipment. The consulting engineer, who wishes to see his plans handled with the judgment necessary to make them a success, should see that conditions are made such that a self-respecting man can live in the plant.

Lubrication of Refrigerating Machinery

EFFECTS OF LUBRICANTS ON PARTS NOT REQUIRING LUBRICATION, AS WELL AS THEIR EFFECTS ON ACTUAL WEARING PARTS, MUST BE CONSIDERED. BY ALLEN F. BREWER*

WITH THE exception of steam cylinder lubrication, where condensed steam is to be returned to the boilers, open feed water heaters, or used for process heating around the works, the lubrication of power plant equipment is essentially a matter of reducing friction. As a result the problems involved are those of pressure, temperature, clearance, and the like. But with refrigeration equipment there is another factor, in that the effects of lubricants on parts not requiring lubrication must be given prior consideration to their effects upon the actual wearing surfaces. In consequence, the selection of lubricants for refrigerating machinery is one of the most important items in the upkeep and maintenance of such plants.

In refrigeration work, the cooled product, whether it be ice, water or air, must be free from contamination. Oil is one of the most detrimental features; its presence in ice, for example, will render this product frequently unsuitable for household or domestic use where there is any possibility or necessity of ice coming in contact with food or beverages. In turn, oil in the cooling system will bring about a reduction in refrigerating efficiency, because unless the oil has an extremely low pour test, it will tend to become so sluggish under low temperatures as to deposit on the interior of the cooling coils, being returned slowly, if at all, to the compressor with the refrigerant. Such a film or coating of oil causes a marked reduction in heat transfer through the coils, serving, so to speak, as an insulating medium.

In selecting lubricants for refrigeration machinery we must, of course, consider the refrigerating media involved. At the present time these include anhydrous ammonia or ammonia gas free from water, known chemically as NH_3; carbonic anhyride, CO_2; sulphur dioxide, SO_2; ethyl chloride, $C_2H_5C_1$; and propane, C_3H_8. While their characteristics vary rather widely from a chemical point of view, and likewise their lubricating requirements, the ways in which they bring about the phenomenon of refrigeration are essentially the same. These methods involve, first evaporation and expansion during which heat is abstracted from the adjacent surroundings; second, compression and condensation to remove this heat from the refrigerant and render it capable of serving once more as a cooling medium.

For a lubricating oil to be suitable for ammonia compressor lubrication it must possess certain definite properties, such as low pour test, preferably below zero Fahrenheit, a flash point above the highest prevailing temperature in the system and a sufficiently low viscosity (i.e. usually not above 200 sec. Saybolt at approximately 100 deg. F.) in order to insure against frothing and emulsification with the refrigerant.

Of course, the exact limitations of any of these characteristics will depend upon operating conditions and the design of the system, such as the average temperature prevailing in the coils, the location of the oil, separator, the method of lubrication and the mechanical condition of the compressor and its component parts.

THE POUR TEST IS AN IMPORTANT CHARACTERISTIC

That the lubricant must retain its fluidity and resist congealment when exposed to the prevailing low temperatures in the expansion or refrigerating side of the system is a fact that renders the pour test perhaps the most generally important characteristic. As a result, an ammonia compressor oil should be a straight mineral, filtered product having a viscosity of from 100 to 250 sec. Saybolt at 100 deg. F., according to the pour test desired. The latter characteristic usually decreases with the viscosity; i.e., a typical 100 viscosity oil will show a pour test of —5 deg. F. or under, whereas, with a 200 viscosity lubricant this may be a few degrees higher.

Necessity for purity cannot be stressed too much, for the presence of any foreign matter such as dust, dirt or water will interfere materially with the proper functioning of the oil. Water, of course, would be especially objectionable, for it would probably freeze on being carried over to the refrigerating coils and by remaining in the system, would reduce the evaporative efficiency. Not only does the above apply to the use of new oil, but also to the oil already in service. Every care should be taken at all times to prevent leakage or entry of water due to dripping or splashing. For this reason, oil cans should not be placed under snow covered pipes.

Straight mineral oils are essential, because fixed oils, such as animal or vegetable products, when used in compounding will not only have a tendency to gum at higher temperatures and congeal at low temperatures, but also will be likely to undergo chemical reactions with ammonia. Fixed oils will also tend to generate free fatty acids, which will probably have a corrosive action on the metallic parts of the system and may also form a certain amount of sludge in event of reaction with ammonia gas.

The importance which can be attached to the flash point will depend upon the type of compression system employed. In the so-called wet system, flash point is not as important as in a dry compression system, because the discharge temperatures will in general be considerably below the flash points of the average satisfactory ammonia com-

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pressor oil. Where a dry compression system is involved, however, the cylinder temperatures will be higher, approaching more nearly the danger line from the angle of flash point. Special attention must therefore be paid to the latter characteristic, for the flash point must be sufficiently high to preclude the possibility of distillation or "cracking" of the oil at the discharge temperature. The usual range in temperature of a dry compression system, above one operating under wet conditions, will be from 40 to 60 degrees.

Viscosity of a lubricating oil is of importance in that it is a measure, to a certain extent, not only of the pour test and flash point, but also of the tendency that the oil will have to froth of emulsify with the refrigerant. In general, the lower the viscosity, the more generally suitable will be the oil and the less the chance of objectionable emulsions occurring. Such emulsions, of course, may be regarded as possessing lubricating value to a certain extent, just as does the lather or emulsion formed by a compounded steam cylinder oil. On the other hand, in the ammonia compressor there will be the possibility of this froth or emulsion passing into the system to cause deposits or clogging. So it should be guarded against as far as possible.

In event of the necessity for the oil film to supply more than the usual amount of piston seal due to scored cylinder surfaces, loose rings and the like, a somewhat higher viscosity may be beneficial. It must be borne in mind that it is quite as important for this oil to form and maintain this seal as it is to lubricate the wearing surfaces. In other words compression must be brought about to the maximum degree, according to the design of the system. Where constructional conditions are as intended, an oil of from 100 to 150 sec. Saybolt viscosity at 100 deg. F. will give the best results. In horizontal machines, however, where wear may often take place more rapidly, or in any compressor with loose rings, a viscosity up to 200 or 250 sec. saybolt may be advisable, in order to maintain the requisite seal and the degree of compression necessary.

Care Necessary in Oil Control

To insure that too much oil does not find its way over to the oil separator and impose more or less of an overload on this apparatus, it is always advisable to regulate carefully the flow of oil to the compressor, wherever possible. Otherwise the separator should be drained or blown back at more frequent intervals, in order to prevent as far as possible any of the lubricant from passing over into the evaporator coils. This of course, would reduce the capacity of the condenser and evaporator and ultimately the system would have to be blown out.

In regard to the time for blowing back, it may be stated that this should usually be done when the oil gage on the compressor indicates that the oil has dropped to approximately 1 in. from the bottom of the glass. The separator should be blown back when the compressor is in operation, the return valves being closed promptly, just as soon as the separator gage indicates that this device is freed of oil, otherwise ammonia will tend to pass through to the compressor case, to increase the pressure therein and possibly cause frothing, emulsification or the formation of deposits.

Where a lighter oil is being used, a certain amount of evaporation may occur when the oil is subjected to the heat of compression, especially in a dry compression system. This will occur regardless of the flash point. As a result there will be a possibility of this vapor being carried over into the system with the refrigerant, to condense therein and, in all probability, to remain in the coils. An effective oil separator will remove the greater part of this oil, provided it is properly located, preventing entry to the condenser. But to bring this about effectually, the separator must be located as close as possible to the condenser. Furthermore, its size is important, for it must permit of ample reduction in the velocity of the gases, in order to enable effective separation. If the main separator is not functioning properly, it is advisable to look to its location. Frequently it may be set too close to the compressor, the rush of hot gases precluding effective condensation and separation of the oil. While but one separator may give perfectly satisfactory service, wherever practicable it will be advisable to locate auxiliary devices of this nature at the lowest point of the condenser and evaporator coils.

It is not always possible, however, to locate the separators in the above manner. In such instances the possibility of high evaporation (of the oil) can be counteracted by raising the viscosity to a certain extent. That is, an oil of, say, 200 to 250 sec. Saybolt viscosity would probably show a lower evaporative tendency than a 100 sec. viscosity oil and should be used therefore under such conditions, commensurate, of course, with the type of system and the pour test required. To check up the efficiency of an oil separator, the amount of oil removed from it can be compared with the amount fed to the compressor, for any measured period of time. Any extensive difference would be an indication of ineffectual separation caused by abnormal evaporation and possibly by improper location of the separator.

Prevention of Leaks

One of the causes for the apparent loss of oil from certain compressors is imperfect sealing of the stuffing boxes, with resultant leakage of oil. To counteract the corrosive effect of ammonia on copper, bronze and other alloys, and the detrimental effect of mineral oil on rubber, it is necessary, as a rule, to build compressor stuffing boxes of cast iron or steel, the same as other parts of the machine, using asbestos or babbitt metal as the packing.

To insure more effective lubrication of the piston rod in its passage through this packing, it is customary in some types of compressors to provide for a hollow space or "oil lantern" between two sets of packing, oil being fed to this oil-way by a hand pump or some form of automatic pressure lubricator. In certain double acting compressors, this oil lantern also serves as an auxiliary means for lubricating the cylinder, oil being intentionally allowed to work past the packing. With certain grades of the latter, oil performs the additional function of protecting the material from the possible corrosive effects of ammonia.

A well lubricated piston rod and a properly functioning oil-lantern are indicated by a glossy, smooth finish on the former, in the shape of an oil film; normal temperatures and the maintenance of a satisfactory seal are shown in the stuffing box. Where it is possible to use pressure lubrication, this procedure is preferred by many on account of the positive results attainable, and the practicability of supplying an amount of oil commensurate with the running speed of the compressor. In many cases, timed lubrication is possible, the oil being supplied at each stroke, if necessary, and at the right moment to insure the best results.

In splash-oiled compressors of the vertical type, lubri-

cation is practically as automatic as is possible, the enclosed crankcase doing away with the need for external means of oiling and, in many cases, the stuffing boxes. Here the oil serves both the compressor cylinder and so-called external parts or bearings in much the same way as in an internal combustion engine. In a splash lubricated compressor the oil level must be carefully watched. The mistake should never be made of adding too much oil, otherwise excessive churning may take place, with the possibility of an excessive amount of oil passing over to the refrigerating system.

Lubricating Vacuum and Absorption Systems

In ammonia refrigeration systems of the vacuum and absorption types, pumps take the place of compressors, the vacuum system, as its name implies, working below atmospheric pressure, the absorption system above atmospheric. In fact, with the exception of the application of heat in the absorption system these two function very much alike.

From a lubricating point of view the pumps are the only mechanism in such systems that require attention. As a result there are really no inherent problems involved, with the exception of selecting a lubricating oil capable of maintaining the requisite seal between the piston rings and cylinder wall. Usually a straight mineral, filtered product, as mentioned above in connection with the compression system, having from 200 to 250 sec. Saybolt viscosity will adequately serve the purpose.

Where such pumps are steam driven, of course, due care must be exercised in the choice of steam cylinder lubricants, especially if the exhaust steam or condensate will in any way come in contact with the ice, as would be the case were the condensate to be used for ice making. As a result, a steam cylinder oil capable of ready and rapid separation from the exhaust must be used and every care taken to feed it sparingly to prevent any excess being carried over. Wherever possible a straight mineral oil should be used for such purposes, on the other hand, where a compounded oil must be used in order to give the proper amount of lubrication due to the steam cylinders, it will be advisable to choose a product composed of a filtered stock of medium viscosity and a high grade of special animal or fixed oil. Filtering is regarded as being conducive to more ready separation of the oil or emulsion from the condensate, thereby reducing the possibility of discoloration or contamination of the ice.

Carbon Dioxide Systems

As with ammonia compression systems, lubrication of carbon dioxide or carbonic anhydride compressors requires consideration of certain operating conditions and constructional arrangements relative to the temperature of the refrigerating coils, the type of compressor, the manner of lubrication and provisions for same, the location and efficiency of the oil separator, and the mechanical condition of the compressor wearing parts. In many ways, the principles of operation of a carbon dioxide system are practically the same as with an ammonia compression system with the general exception that higher pressures (up to 1000 lb.) may be involved, requiring heavier constructional details to insure safety and rigidity.

By virtue of these higher pressures, the cylinder temperatures in a carbon dioxide compressor will usually be relatively higher than those in an ammonia compressor. This, of course, must be taken into account when selecting compressor oil, for the flash point should be sufficiently above the discharge temperature to insure against partial distillation. In addition the pour test must be below the temperature of the refrigerating coils to attain the best results. To meet these conditions, a straight mineral filtered oil is best, having a medium viscosity range of from 100 to 250 sec. Saybolt as approximately 100 deg. F. The question of reaction occurring between the hydrocarbon constitutents of the oil and carbon dioxide is fortunately of but little moment, for the affinity existing between the two is practically negligible. As a result, the only chance of oil being carried over into the condenser arises in case it is vaporized; if the flash point is sufficiently high this should rarely occur.

Oil traps and properly designed stuffing boxes are quite as essential to effective operation of a carbon dioxide system as to one using ammonia. Stuffing boxes, however, usually require more compartments on account of the higher pressures involved. They are, in general, pressure lubricated by some force feed oiling device, for it is absolutely essential to counteract the possibility of leakage of gas by oil pressure. This latter requires accurate control, however, for if too much oil is delivered the pressure in the stuffing box may exceed that of the compressor, with the result that a certain amount of oil might pass to the gas relief line and refrigerating system, especially where the oil trap or separator might not be properly located or capable of functioning as intended.

Ice Cans and Compressor Valves Demand Attention

Prevention and Stoppage of Ice Can Leaks and Determination of Lift of Ammonia Compressor Valves Discussed by N.A.P.R.E. Members. By Chas. H. Herter

ANOTHER INTERESTING meeting of New York Chapter No. 2, N.A.P.R.E. was held recently at the Continental Hotel, Broadway and 41st St., New York City, at which, after the routine business of the chapter had been transacted, an interesting discussion of various phases of refrigeration plant operation was held by the members. The principal points in this discussion are given below.

Stopping Ice Can Leaks

Answers were first sought as to methods recommended for stopping leaks from standard 300-lb. can ice tanks. Such leaks should be stopped, because the escaping brine is likely to destroy the cork insulation and damage the building, or spoil the ice in storage. Leaks occur at various places as follows:

Obviously the packing of horizontal shaft brine propellers should be kept reasonably tight and a drip gutter provided to keep brine away from the insulation. Lignum vitae wood bearings are found most satisfactory. Hemp packing greased with tallow can be used in the stuffing box.

The ½-in. diameter rubber packing ring used between propeller supporting bracket and end wall of tank is likely to decay in time and will cause leakage. A more durable packing, such as asbestos sheet, should be used.

These two difficulties are avoided in vertical shaft propellers. To reduce the first cost, manufacturers supply small diameter vertical agitators with high speed motors, resulting in poor efficiency. Mr. Arvidson therefore sug-

gested the use of a large, slow-speed, brine agitator, with shaft placed at an angle of 10 or 15 deg. to the tank bottom.

Other places for leakage are the 1¼ or 2-in. pipe tank stuffing-boxes at bottom of end wall for liquid feed pipes. These are designed for very little packing and are likely to be buried in the wall insulation. The best practice now does away with stuffing boxes by running the liquid feed pipes downward within the tank, 2 or 3 ft. from the end wall.

Some manufacturers run a 2 or 2½-in. steel angle all around the tank top, 4 in. below upper edge, to act as support for tie braces and frame work for covers. As the brine level varies and is likely in some places to rise close to the top of the tank, brine can escape at rivet or bolt holes in the angle, unless provision is made for securing a tight joint. Evidently it would be best simply to weld the angle to the tank wall. The remedy suggested for leaky angles was the use of "Alomel" as made by Werner Paint Co., Hoboken, N. J., forced in with a grease gun as in the Alemite system applied for lubricating automobiles. Presumably "Smooth-On" cement would be satisfactory in this case too.

Thawing Tanks Sometimes Overflow

Leakage frequently charged to the ice tank really comes from the overflowing of thawing tanks, the water running down over the end wall insulation and creeping under the tank. For this reason the dipping tank ought to be kept away from the ice tank, and, to prevent water from entering the leverator shaft, the dumpers should be kept at least 6 ft. from the shaft. Special precautions should be taken to have an impermeable apron or protection over the wall and bottom insulation of the ice tank.

All these sources of leakage can be readily attended to, but if the steel tank leaks in the seams of bottom and side sheets, it becomes a difficult and expensive problem, so that in many cases this work is postponed indefinitely. Relief is sometimes obtained by throwing bran or cornmeal into the tank, which lodges over leaky cracks, and it may be possible to accomplish the same object with sufficient hydraulic Portland cement. E. Hatch reported that electric welding was a sure cure. He knows of a case where four 50-t. ice tanks with total 2864 t. cans of 300 lb. each had been welded for about $3600, equivalent to $1.25 per can, exclusive of the work of emptying and cleaning the tanks and replacing coils, framework, cans and covers.

Proper Size Plate Valves Necessary for Good Operation

The writer pointed out that one of the objects of these meetings was the education of engineers, to enable them to increase the economy of the machinery in their charge. By far the greatest opportunity for immediate success could be found in the improvement of the valves in ammonia and air compressors. Formerly, he said, it never occurred to engineers to analyze the design of the machinery in the plant, and thus enormous losses continued for years. If one did not command the necessary knowledge, one could take the matter up with the manufacturer, or with valve specialists or with capable consulting engineers, and it would generally be found that the substitution of ample size plate valves for the old valves would improve the performance 10 to 25 per cent. He referred to his talk on this subject given on March 19, sketched on the blackboard a modern plate valve and showed in detail how the gas velocity through the valves could be arrived at by simple arithmetic. He said it was necessary to calculate separately the exact net effective flow area in plan through the valve guide, through the valve body or seat, and through the lifting edges of the valve plates or rings, which latter equalled the periphery of all inside port edges in inches, multiplied by the lift, such as ⅛ in. or 0.125 in., which gave the total lift area per valve. The lift, of course, was equal to the distance between seat and step, less the thickness of the valve plate.

Calculating Area of Valve Opening

Even plate valves may not give best results if there are obstructions to flow. The smallest area existing in the whole valve passage was the area used for calculation. Referring, then, to L. H. Jenks' paper on "Effect of Speed on Compressor Capacity and Power" read Nov. 30, 1925 at the annual meeting of the A. S. R. E., one could check the calculations by the figures derived from that paper, as follows:

Calculating Gas Velocity

One Frick compressor cylinder, horizontal, double acting, 10½ × 18 in.

1. Net piston displacement in cu. ft. per min. equals net piston area in sq. ft., times stroke in ft., times revs. per min. Thus, head end volume equals 10½ in. diam. = 86.59 sq. in. ÷ 144 = 0.60132 sq. ft. × 18/12 ft. = 0.90198 cu. ft. per rev.; × 200 revs. per min. = 180.396 cu. ft. per min. Crank-end volume equals: 10½ in. diam. = 86.59 sq. in.; less area of 2½ in. diam. piston rod or 3.5466 = net 83.0434 sq. in.; 4 ÷ 144 = 0.57669 sq. ft.; × 18/12 ft. = 0.86503 cu. ft. per rev. × 200 rev. = 173.007 cu. ft. per min.

Evidently there is but 95.6 per cent of the head-end volume to be pumped through the crank-end, which is sometimes reflected in a lower m.e.p. for that end. However, the work of the crank-end valves is more severe because of the shorter time available for expelling the gas. Expulsion of gas occurs within about the last 20 per cent of stroke. On the forward stroke there are, with a connecting rod 3 strokes long, 57.3 deg. of crankpin travel available, while on compression stroke toward head-end, only 49.6 deg. are available (see Kent's Handbook) which means but 86.6 per cent time when we ought to have 95.6 per cent. Hence the velocity through the crank-end discharge valves is fully 10 per cent greater than through the head-end valves. However, engineers usually calculate the average gas velocity due to the whole piston displacement.

2. As there are only two suction valves of 4 sq. in. each (lift 3/16 in.) available at a time to gas flow, the average suction gas velocity is 353.403 cu. ft. ÷ 8/144 = 6361.2 ft. per min.

3. There are two discharge valves of 3 sq. in. each available (lift ⅛ in.) hence the average velocity of gas through discharge valves is 353.403 cu. ft. ÷ 6/144 = 8481.7 ft. per min.

4. The lower the gas velocities the more efficient is a compressor likely to be. Let us determine the gas velocities found in the 11 × 13 in. York vertical single acting compressor referred to by Thomas Shipley at our New Orleans Convention, Nov. 13, 1924: Combined displacement of two cylinders equals: 11 in. diam. = 95.033 sq. in. × 13 × 2 = 2470.858 cu. in. per rev. × 180 revs. = 444 754.44 cu. in. per min. ÷ 1728 = 257.381 cu. ft. per min.

5. Each cylinder has four 2.3 sq. in. suction valves in

piston (poppet type, lift 3/8 in.) resulting in a mean suction gas velocity of

$$257.381 \div \frac{4 \times 2.3}{144} = 4028.57 \text{ ft. per min.}$$

6. The discharge gas velocity through 3 poppet valves with 3/8 in. lift, equals 257.381 ÷ 6.51/144 = 5693.21 ft. per min. Evidently one should aim to reduce the gas velocities to at least the figures here given.

G. Savarese related instances where changes in valves had resulted in great improvement, and Mr. Vecchie spoke of difficulties he is experiencing with high speed compressor valves having too small a lift (3/64 in.) The above suggestions should enable engineers to locate the cause of their valve troubles.

Mr. Arvidson sketched on the board a 2-can filling tank arrangement provided with one balanced shut-off valve actuated by a large float cylinder 8-in. diam., 14 in. long, which is giving him good results and uniform weight of ice.

Arthur P. Miller contributed the following practice problem for mathematically inclined engineers. Three different sized pipes are able to fill a tank in 60, 45 and 15 min. respectively. How many minutes does it take to fill this tank with all three pipes flowing. This puzzle was soon solved, and is added here for the entertainment of others.

Steam Plant or Diesel Engines?

COMPARISONS SHOW SEASONAL HEATING NEEDS MUST DECIDE CHOICE OF PRIME MOVERS. BY EINAR WINHOLT

DURING RECENT years the Diesel engine has gradually forged its way to the front in the United States. If power alone is to be considered, it is the most economical of all prime movers. But in most of the northern states of this country, heat is as of much importance as power and for 6 to 8 mo. of each year the manufacturer's problem is not only one of power, but power and heat.

When this combination is considered, we at once have the answer to why the Diesel engine cannot accomplish in this country what it has in Europe. Even one who knows only the mere fundamentals of power and heat must realize that during the heating season the average industrial plant not only can obtain power from its steam plant but can utilize the exhaust steam for heating. It is obvious that in so doing the power is a by-product and costs practically nothing.

Instead of theorizing, however, let us consider a concrete example. In an ordinary manufacturing plant, located where the heating season usually begins in early fall and continues to late spring, there is 100,000 sq. ft. of radiation for heating. This will require approximately 800 b.hp. for average weather and about 1000 b.hp. when the temperature ranges from zero to 10 deg. above. The electric load of the plant is from 700 to 1000 kw-hr. It is evident, therefore, that whether electric power is purchased or manufactured, a 1000 b.hp. steam plant must be available for heating.

Operating during warm weather, when no heat is required, even with a non-condensing unit, a water rate of approximately 30 lb. per kw-hr. may be expected. With a boiler efficiency of 70 per cent, the thermal efficiency of the combined boiler, power and heating plant will be about 8 per cent with this water rate. If the prime mover is operated condensing and assuming a water rate of 18 lb. per kw-hr. with the same boiler efficiency, the thermal efficiency will be approximately 13 per cent.

But during the time the exhaust steam is used for heating, the thermal efficiency of the plant will be 70 per cent, if the boiler efficiency is still maintained at this figure.

STEAM PLANT SHOWS HIGH AVERAGE YEARLY EFFICIENCY

Now, if we assume a heating season of 6 mo. with a thermal efficiency of 70 per cent and non-condensing operation during warm weather at 8 per cent, the average efficiency of the plant for the entire year will be 39 per cent. How does this compare with the best yearly average of a Diesel plant? Assuming that sufficient heat from the jacket water and exhaust gases could be reclaimed from a Diesel installation to bring its thermal efficiency up to 39 per cent and further assuming that fuel in both cases could be purchased on the same B.t.u. per dollar basis, the Diesel plant would give the same results as steam.

But here the favorable comparison ends, for, in addition to the fuel for the Diesel engine, a sufficient amount must be purchased to heat the plant for 6 mo. of the year. If, as previously stated, the plant will require approximately 800 b.hp. per hr. for heating and assuming a coal consumption of 3.5 lb. per b.hp., the fuel consumption for heating load alone will amount to 6000 t. of coal in 6 mo. At $3.50 per ton, the heating bill will be at least $21,000.

This does not require an engineer to determine which method to choose, for any business man or plant executive can see that the steam power plant is the more economical when it comes to a question of both power and heat.

DIESEL ENGINES ECONOMICAL WHEN HEAT NOT NEEDED

Where the power requirements are greater than the demands for heat, a Diesel plant should be considered. This holds true, especially in water works, ice plants, and other establishments where practically no heating is required but where there is a constant demand for power 24 hr. per day. In many places in the southern states, where heating requirements need not be considered and the cost of oil is low, a Diesel plant may supply power at a figure far below that of any other prime mover.

In the preceding comparison between Diesel and steam-operated plants, consideration has been given only to the efficiency of operation and the cost of fuel. No attempt has been made to compare original costs, fixed charges, labor or maintenance, as such items naturally depend on local conditions which must be worked out for each case.

A STUDY OF THE comparative composition of various coal tars is being conducted at the Pittsburgh, Pa., experiment station of the Bureau of Mines, Department of Commerce. The purpose is to apply analytical methods now practically standardized by the bureau to representative tars from various sources, obtaining thereby a uniform comparison of their composition and value. At present there are no reliable analytical data available which will serve as a basis for comparison and evaluation of coal tars, particularly low-temperature tars. Six tars were selected as representative of the best known low-temperature carbonization methods employed in this country. These have been subjected to uniform methods of analysis developed in the Bureau of Mines laboratories, and the results compared with those obtained for a coke-oven tar and a water-gas tar.

New Metallic Gland Packing Gives Service

FROM time to time new designs of packing make their appearance, most of them being intended for a specific purpose, but few having real practical value. The packing, however, shown in Fig. 1 is really a simple form of metallic packing specially suited for the rods of high speed steam engines. At the base of the gland is a gun metal ring *A*, followed by a ring of the packing *H*, a cast-iron lantern bushing, *C*, two more rings of packing *B'* and *B"*, and finally a ring of soft asbestos *D*, followed by the gun metal gland *E*. The rings, *B*, *B'* and *B"*, are of a special alloy cast in the form of rolls about 12 in. long and 6 in. diameter

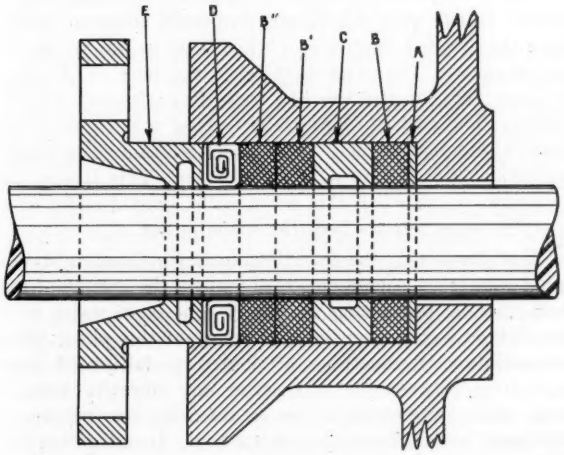


FIG. 1. SIMPLE FORM OF METALLIC PACKING FOR RODS OF HIGH SPEED STEAM ENGINES

and after being shaken in a "rattler" to remove the surface metal, are turned in a lathe by a special tool. This tool takes off the metal in the form of a thread which is collected into skeins. The metal in this state is plaited and impregnated with graphite and heavy mineral oil. The plaits are then cut into suitable lengths and pressed into rings with a diagonal joint. This is done in a die and during the pressing the surplus oil is exuded.

In use the packing is screwed up fairly tight and a new packing after being taken up once or twice requires little adjustment, remaining steam tight for long periods without any tendency to cut the rod. It is claimed to have all the virtues of the best metallic packing, while being as simple as it is possible to make it.

Figure 2 shows another type of special packing, which also is specially suited to high speed engines, the idea being to exclude steam from the stuffing box. There are two floating packing boxes *A* and *A'* kept apart by the spiral springs *B* and *B'* which also keep the packing in the boxes tight. The faces *C* and *D* are ground and the springs keep the packing boxes steam tight against these faces. It will also be noted that the boxes have segmental ends working against the pieces *E* and *E'* which provide freedom of move-

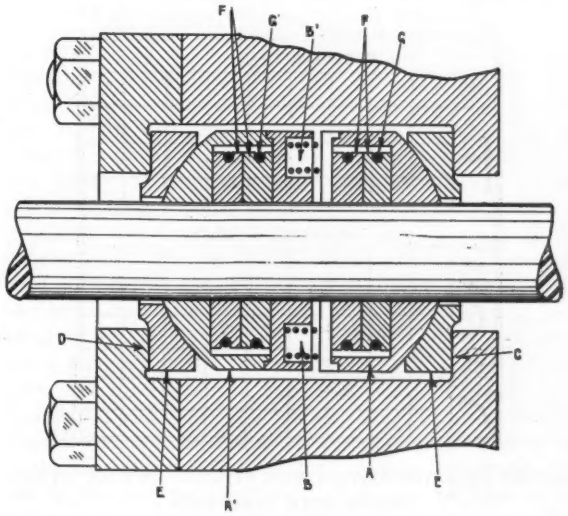


FIG. 2. SPECIAL DESIGN OF METALLIC PACKING INSIDE OF FLOATING BOXES AND HELD ON THE ROD WITH COIL SPRINGS

ment. Inside these boxes are disposed the actual packing blocks *F* and *F'*, held against the rods by springs *G* and *G'*. There are only two vertical ground joints which are kept together by the springs *G*, but there is practically no steam pressure in the stuffing box, first, due to the ground faces between *C* and *E* and secondly, to the fact that the blocks *F* are a ground fit between the faces of the floating boxes.

Warrington, England. F. JOHNSTONE-TAYLOR.

Pipe Lines Should Be Direct and of Ample Size

I RECENTLY had the pleasure of straightening out one of the worst refrigerating plant layouts I ever saw. An analysis of this job may be of value in pointing out how an installation should not be made.

This is a compression plant. The liquid line from the double-pipe condenser takes a vertical drop to the floor, along the floor and then up to the top of a vertical receiver. This construction forms a most excellent pocket for the accumulation of impurities. They eventually plugged up the line completely. I raised the condenser and made as straight a connection as possible to the receiver; that cured the trouble there.

My attention was next directed to the suction line. It was supposed to have been a ¾-in. pipe all the way from

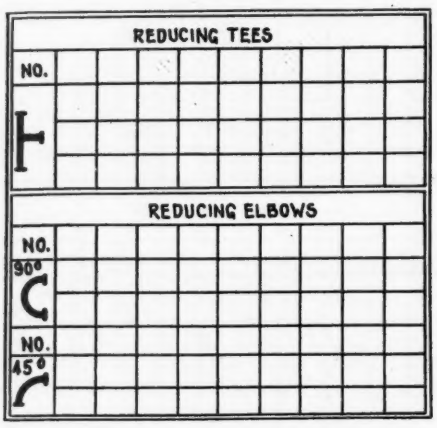
the expansion coils to the compressor but I found a variety of sizes there. From the ¾-in. suction header the size was reduced to ⅜ in., then raised to ½ in., through a ½-in. valve, then again increased to ¾ in. to the compressor. I took out all of this and replaced it with a ¾-in. line.

With these changes the friction load was so reduced that the plant is now easily able to operate at its rated capacity.

S. G. Rogers.

Novel Form for Checking Pipe Fittings

Here is an ingenious and simple method for keeping a record of pipe fittings which the writer believes is entirely new. It was developed by an engineer friend who is with a large eastern engineering company.



MAKING AN INVENTORY OF PIPE FITTINGS IS EASY WITH A BLANK FORM LIKE THIS

For example, where reducing tees have three different sizes of openings, as often happens, the problem of recording those openings in an orderly manner has heretofore always been a stickler. The accompanying reproduction of a blank form used by this engineering concern shows how easily it can be done.

Similarly, reducing elbows and return bends can be checked or recorded on the same form which tells the whole story without the necessity of vexing explanatory remarks such as are to be found attached to the usual variety of pipe fitting records of this character.

Newark, N. J. W. F. Schaphorst.

Exhaust or Live Steam Heating

There are engineers who believe that exhaust steam which has passed through a steam engine running idle is better for use in radiators than the steam which passes through a reducing valve.

Personally I believe they are mistaken for although it may be true that the exhaust steam from an engine running idle will be superheated to a small extent, it is also true that the steam passed through a reducing valve will be superheated probably to a greater degree. In the case of the engine more heat is lost to friction and radiation than with the reducing valve, although ordinarily tests will show the same quality of steam in each case.

The theory that the pulsations of the engine in some mysterious way extract more heat units than may be found with the reducing valve has not been proved. Many questions and calculations have been made in an attempt to show why the engine exhaust is better than live steam for heating but with the ordinary high pressure engine using steam direct from the boilers without any supplementary heating around the cylinder or elsewhere, I believe it is impossible to get more heat out of 100 lb. of any kind of exhaust steam which has not been superheated from a source other than that which is contained within itself than it is possible to get from 100 lb. of dry live steam at the same pressure when used for heating.

In many instances when using exhaust steam for heating or else an equal amount of live steam at different periods of the same day, I found that practically the same amount of coal was burned when the machines were closed down and live steam was used.

My opinion is that it is safe to take for granted that live steam or exhaust steam at equal pressures will give equal results in a heating system. That wet steam will give up its heat quicker than dry steam under the same outside conditions does not appear probable.

Toronto, Canada. James E. Noble.

Reasons for Bags in Boiler Shells

Bag developments at the bottom of horizontal return tubular boilers over the furnace fire are a common occurrence the affected condition of which may be due to one of several causes. The cause definitely given by F. E. Hussey on page 1284 of the Dec. 15 issue is a physical impossibility. The editor appropriately noted this cause to be doubtful but that sudden opening of the steam valve would conceivably lift the surface of the water. This is true, as a vacuum is caused in this event with forceful effect only upon the water surface near the steam outlet.

Most frequently the contributing factor found in developing bags is the accumulation of scale at the bottom of the shell, thereby preventing the direct contact of water with the plate and consequently overheating of this plate. This accumulation is sometimes attributed to falling of loose scale from between the tubes after any vibrative work is done, either in cleaning tubes or renewing one without a final shell bottom inspection or washout. Investigation has determined definitely this evidence as having caused a bag.

In some cases bags may be due to the adherence of oil which finds its way into the boiler through the feed water system. When engine or lubricating oil adheres to the water surface, it acts as a heat insulator. If it happens to settle upon the surface directly above the flame, a bag in the shell will be the result, provided the temperature reaches sufficient intensity. Investigation determines this evidence as the cause by detecting a powder-like discoloring, the shades differing with the quality of the oil.

Bags, pockets or bulges in the shell over the fire have occurred on account of the metal of the shell plate being of inferior quality, having such defects as slivers, laminations, blisters or slag clots, produced while the plate was in the process of manufacture. The strength of such a defective plate is consequently decreased and in time becomes so weak in the defected area that a pocket or bulge is produced on account of insufficient strength to resist the forces acting upon it. Investigation will also disclose this evidence as the cause in this case.

An occasional cause of bag development is by firing up without water in the boiler through negligence or

ignorance. It may seem absurd in this day of advanced power plant efficiency even to mention this particular cause —but it has happened and, it is safe to say, may happen again.

Now, in determining a cause for bag development where investigation discloses no tangible or visible evidence, a feasible theory frequently discussed by engineers is the multiple concentration and ever rapid formation of steam bubbles rising or rather amassing over a spot at the shell bottom where the heat is most intense. This theory is not as yet an established fact but there has been sufficient proof to show that a bag will not develop (unless it is from any of the above stated causes) where heat is evenly distributed over the heating surface.

To substantiate this theory, it has been observed that in nearly every case of bagging coming to our attention not showing any evidence of any of the above stated causes, there has been a stoker where the combustion rate is so high that the temperature produced is intense and its action upon the immediate area of the shell causes such a rapid evolution of steam bubbles as to prevent water displacement at the same rate of rapidity. As this partially keeps the water from the hottest part of the shell, a bag is most likely to develop.

Jersey City, N. J. T. P. TULIN.

Economy Builders

WE ARE arriving closer and closer to the point where guess work in the boiler room, manual labor, and much mental labor will be eliminated. At the recent Power Show several concerns demonstrated devices that automatically keep the pressure where it belongs by speeding the stoker up or down, regulating the damper, balancing the draft, and keeping the CO_2 at the right point. One of these devices is electrical and the others are mechanical. Some of them are in actual operation in very large power stations and it is claimed that they are doing their work well. Like mechanical boiler feed regulation, damper regulation, temperature regulation, pressure regulation, and most other modern automatic regulation, automatic combustion control will give us far better regulation than human regulation can possibly give. Mechanical devices don't forget, do not become fatigued, are willing to work day and night, do not go on strike, and can be made more sensitive to temperature and pressure changes than can the human being. Automatic combustion control is a modern necessity both from the standpoint of fuel conservation and of labor saving. We haven't enough laborers in this country today and besides fuel is becoming so costly (due to scarcity of labor) that engineers can no longer afford to be bothered with inefficient hand labor. Engineers should have opportunity to think and handle power plant problems scientifically. Automatic combustion control gives them that opportunity.

The best industrial power plants of today as well as the large central power stations, are having nearly everything of importance recorded permanently by means of recording instruments.

What was the temperature of our chimney gas yesterday before and after each soot cleaning?

What effect did the soot cleaning operation have on the draft? On the CO_2? On the superheat temperature?

What was the average CO_2 during last month and the corresponding month last year?

How much steam passed through pipe "C" last week?

Have furnace temperature conditions been improved during the past year?

How does the boiler feed water regulator act during peak loads?

A few years ago the standard answer to questions like that was, "I don't know." Today any one of them can be answered by the chief engineer of a modern power plant without leaving his room. He can tell you the exact conditions right now as regards any one of the above items. It is a good, healthful, economical state of affairs, worthy of adopting to a reasonable extent by the smaller plants. In most instances recording instruments soon pay for themselves. Nearly any instrument that makes for greater fuel saving soon pays for itself.

Newark, N. J. W. F. SCHAPHORST.

Oil Separators Give Results

SOME TIME ago the writer appealed to readers for suggestions as to the best way to remove cylinder oil from steam engine exhaust. As we have recently accomplished our purpose by installing oil separators and, with the thought in mind that some reader might be interested in a few details of the installations, I wish to offer the following suggestions:

Get a separator approximately twice as large as the exhaust line. In our case we installed a 14-in. separator on an 8-in. line. If possible, install a run of pipe the same size as the separator and approximately six diameters long, ahead of the separator. On the exit side of the separator, use a reducing flange and connect directly to the exhaust line. Use a reliable trap, preferably of the multiple type, for handling the oil from the separator. This oil may be reclaimed by a simple separator comprising two pipe risers in the form of a U tube. Oil, being lighter than water, will rise higher and may be drawn off for use on bearings or wherever an inferior oil is satisfactory.

We are now using condensate in our bleach plant and so far have not detected any oil.

Lincoln, N. H. A. P. NUTTER.

Rust Causes Shaft Gland Trouble

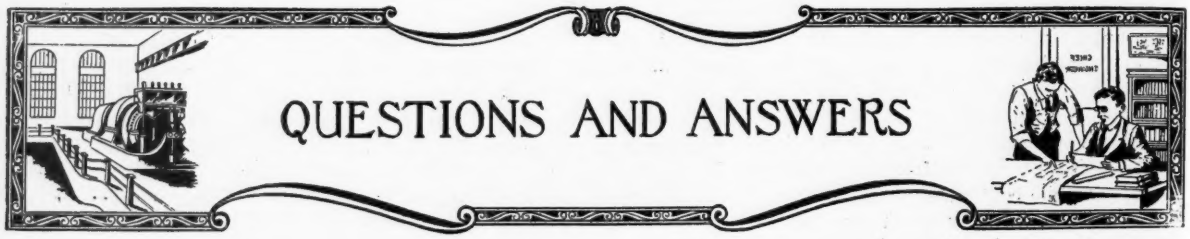
IN THE PLANT where I am employed there are three turbo-alternators which require water at a low pressure of about 4 to 8 lb. to seal the shaft glands from air leakage. This water is drawn from an iron tank of about 300 gal. capacity, placed at sufficient height to get the desired pressure.

For years we had a continual source of trouble by rust accumulating in the tank and passing along with the water, then finally lodging in the fittings, stopping the supply of water and necessitating removal of the fittings for a thorough cleaning. This had to be repeated about once a month.

This trouble has been entirely eliminated by 3 applications of rust resisting paint which form a "carbon coat" on the metal surface. The paint was applied about a year ago and there has been no trouble since.

New Bedford, Mass. R. G. SPOONER.

BANGOR, ME., has voted to buy a centrifugal water pump of seven million gal. capacity, with a simplex electric motor and other equipment at a cost of about $20,000. The measure is passed to protect the city's water supply owing to uncertainty through ice conditions.



Flue Gas Temperature and Drafts

WHAT IS the draft loss through a two or three pass water tube boiler of the B. and W. type with inclined tubes, horizontal drum and vertical baffles? What are the flue gas temperatures with this type of boiler?

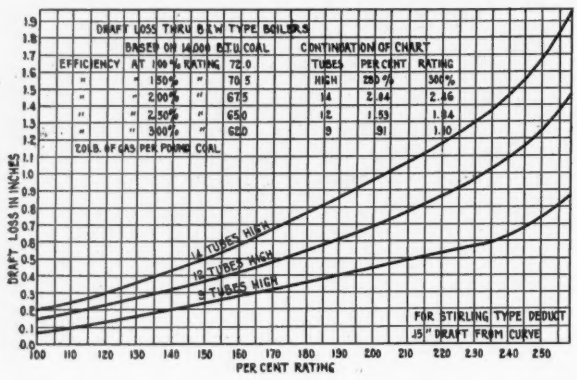

DRAFT LOSS THRU B&W TYPE BOILERS
BASED ON 14,000 B.T.U. COAL
EFFICIENCY AT 100% RATING 72.0
" " 150% " 70.5
" " 200% " 67.5
" " 250% " 65.0
" " 300% " 62.0
LBS. OF GAS PER POUND COAL
CONTINUATION OF CHART
TUBES HIGH | PER CENT RATING
14 | 200% 2.84 | 300% 2.46
12 | 1.53 | 1.34
9 | .91 | 1.10
14 TUBES HIGH
12 TUBES HIGH
9 TUBES HIGH
FOR STIRLING TYPE DEDUCT .15" DRAFT FROM CURVE
DRAFT LOSS IN INCHES
PER CENT RATING

FIG. 1. CURVES SHOW DRAFT LOSS THROUGH WATER TUBE BOILERS AT VARYING LOADS

Please give the draft loss and flue gas temperatures at various loads for the average horizontal return tubular boiler of about 150 hp. J. A. P.

A. Because of great variation in the size and design of boilers, the variety of baffle arrangement and the wide range in operating conditions, it is impossible to establish rules for draft losses which can be of general application and it is advisable to obtain specific data from the manufacturers.

The draft loss will depend upon the rate of combustion, also on the velocity of the gases passing through the furnace which in turn is dependent on the kind of draft, that is, whether it is natural, forced or induced.

In general it might be stated that with 2-pass horizontally baffled boilers of the type you mentioned, the pressure drop through the boiler is from 55 to 65 per cent of the total draft at the stack side of the damper. The draft loss with return tubular boilers is from 45 to 55 per cent.

In Fig. 1 are shown curves for the draft loss through water tube boilers with a given fuel and amount of excess air. In Fig. 2, Curve A shows the range of flue gas temperatures found to be the average for several of the better known makes of boilers. Curve B was plotted from data taken from Marks Mechanical Engineers' Handbook.

Above 100 per cent of boiler rating, curve B allows somewhat higher temperatures than curve A, for the same boiler output. It averages about 25 deg. higher with 35 deg. as the greatest difference at 250 per cent of rating. With modern forced draft stokers or with oil firing, however, flue gas temperatures need never exceed the values shown in curve A. In many cases of good operation temperatures fall considerably below. If they are above it is high time to look for leaky or faulty baffling or dirty tubes.

It should be borne in mind that there is no definite rule for determining the exact flue gas temperature which should exist with any given percentage of boiler rating or excess air. There are so many different makes of boilers and different models of the same make. In general, flue gas temperature varies somewhat inversely as the draft loss through the boiler. As the output of the boiler increases, the curve of draft loss becomes steeper while the curve of temperature shows practically a straight-line increase up to 150 per cent rating after which the increment gradually becomes less. As shown in curve A, between 150 and 200 per cent rating the increment is 55 deg.; between

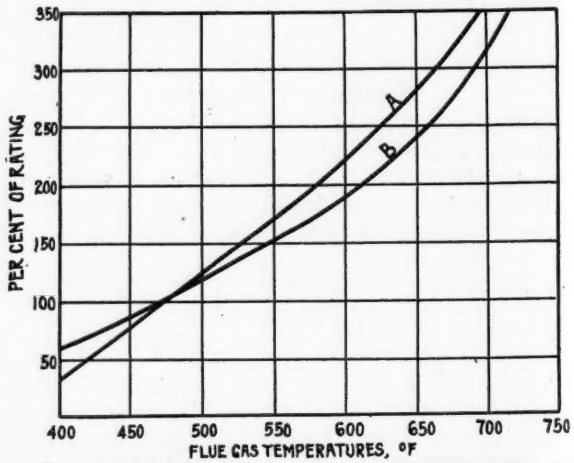


FIG. 2. THESE CURVES SHOW FLUE GAS TEMPERATURES AT VARYING LOADS FOR WATER TUBE BOILERS

200 and 250 per cent rating the increment has dropped to 46 deg., while between 250 and 300 per cent it is only 39 deg.

Boilers of the Stirling or V-type generally have 0.10-0.15 in. less draft loss through the boiler than boilers of the B. and W. type.

For general all-around working conditions, temperatures as shown in Fig. 2, curve A may be applied to any and all makes of water-tube boilers having two or three passes.

In the same manner that no definite statements can be given for draft losses, neither can they be for flue gas temperatures with horizontal return tubular boilers, since there is likely to be more variation in combustion conditions with hand fired than with stoker fired boilers.

In general, with about 50 per cent excess air, the following temperatures at various per cents of rating may be found with horizontal return tubular boilers:

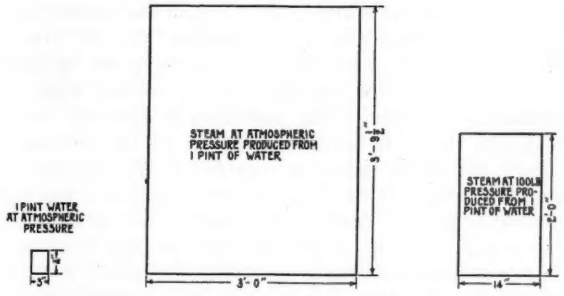
Rating	Temperature
100	500
150	575
200	645
250	700

Relative Volume of Water, Steam and Ice

IF A PINT of water is turned into steam what volume will it occupy; also what will be its volume if changed to solid ice? S. S.

A. Water in the liquid state is denser than either of its other forms—steam or ice.

The volume or cubical space which steam occupies depends on the pressure. A pint of water weighs approximately 1 lb. and fills a space of 28.88 cu. in. or about 0.017 cu. ft. When this water is turned into steam and confined in a tank at atmospheric pressure, it will occupy a space of 26.8 cu. ft. or the tank holding the steam would have to be 1575 times as large as the pint measure holding the water. If this tank were of cylindrical shape, say, 3 ft. in diameter it would need to be about 3 ft. 9½ in. high.


1 PINT WATER AT ATMOSPHERIC PRESSURE
STEAM AT ATMOSPHERIC PRESSURE PRODUCED FROM 1 PINT OF WATER
3'-0"
STEAM AT 100LB PRESSURE PRODUCED FROM 1 PINT OF WATER
14"

IN CHANGING FROM LIQUID TO VAPOR A PINT OF WATER EXPANDS 1575 TIMES AT ATMOSPHERIC PRESSURE AND ONLY 228 TIMES AT 100 LB. GAGE

If a pint of water were turned into steam and put into a tank at 100 lb. gage pressure the tank would be much smaller and would need to have a capacity of only 3.88 cu. ft. which would be the volume of a tank 2 ft. in diameter and about 14 in. high. The steam would expand 228 times its original volume. In the accompanying illustration the relative size of a pint of water is compared with the size of a container necessary to hold the steam produced from this water at atmospheric pressure and at 100 lb. pressure.

If a pint of water is frozen into solid ice at 32 deg. it will expand although not nearly as much as when changed from liquid to vapor, the volume changing from 28.88 cu. in. to 30.07 cu. in. The ratio of expansion is 1 to 1.086.

Capacity of an Ice Machine

PLEASE tell how to figure the ice making capacity of a single compressor, 19 in. by 19 in. The head pressure is 180 lb. gage, the back pressure is 20 lb. gage, and the compressor runs at 160 r.p.m.

What is the length of time necessary to freeze a given quantity of ice? J. E. B.

A. We will assume that your ice machine uses ammonia as a refrigerant, although no particular fluid was stated. The capacity of an ammonia refrigerating machine depends on the number of pounds of ammonia handled per minute and the pressures between which the compressor operates. The higher the back pressure, the greater will be the weight taken in for a given size of cylinder, and the lower the head pressure the less will be the heat which must be extracted in the condenser. The calculation of compressor capacity, therefore, resolves itself into two parts; first, determining the refrigerating effect of a pound of ammonia working between the head and back pressures; second, determining the number of pounds of ammonia that the compressor can handle.

For the first, $r = h_1 - (t - t_1) s$;

Where, r = refrigerating value of 1 lb. of ammonia, B.t.u.;
s is the specific heat for ammonia, taken as 1.0;
t is the temperature at head pressure for saturated ammonia;
t_1 and h_1 are the temperature and heat of vaporization respectively at the back pressure, for saturated ammonia.

Values used are taken from a table of Properties of Saturated Ammonia, having given the head and back pressures. At 180 lb. pressure, the temperature is 94.3 deg. F. With a back pressure of 20 lb., the temperature is 6.5 deg. and the heat of vaporization is 567 B.t.u. The value of r therefore works out to 479.2 B.t.u. absorbed per pound of ammonia handled. To get the refrigeration capacity of the compressor, we multiply the cubic foot capacity of piston displacement per minute by the refrigerating value of 1 lb. of ammonia, as already calculated, divided by 200 times the specific volume at back pressure. From the ammonia tables we find the specific volume at 20 lb. is 7.93 cu. ft. per lb. The area of a 19-in. cylinder is 283.53 sq. in. and the volume with a 19-in. stroke is 283.53 times 19, or 5387 cu. in. 5387 divided by 1728 equals 3.12 cu. ft. 3.12 times 160 (r.p.m.) equals 499.2 cu. ft. per min. capacity.

The number of tons refrigerating capacity of the machine per hour may be found by the following formula:

$$T = \frac{C \times r}{V \times 200}$$

Where, T equals tons refrigeration capacity of machine per hour;
C equals cubic feet piston displacement per minute;
r equals refrigerating value 1 lb. of ammonia B.t.u.
V equals specific volume cu. ft. per lb. at back pressure.

$$\text{In this case } T = \frac{499.2 \times 479.2}{7.93 \times 200} = 150 \text{ t. capacity.}$$

Forty-eight to sixty hours are usually required to freeze a 20-lb. block, depending on the speed of brine circulation.

Sharp Points at Top of Admission Line

IN THE Dec. 15 issue, p. 1286, the indicator cards by Tom Jones show late admission but are quite acceptable. The points A-A at the top of the admission line may be caused by several things. Probably he has considerable lap on the steam valves, which are moving quite fast when admission takes place and the sudden rush of steam causes the spring and the pencil motion on his indicator to jump slightly. As he has a high piston speed (750 ft. per min.), he might advance the eccentric and lengthen the dashpot rods a little and I think he will get a perfect card.

Another cause of the sharp points might be that the steam pipe is not large enough, thus causing the steam line to drop slightly.

Leominster, Mass. A. O. GATES.

EDITORIAL COMMENT

Changing Conceptions in Electricity

In a paper delivered before an assemblage of engineers in Chicago recently, Dr. Joseph Slepian outlined a new theory of power flow in electric circuits. This theory which is discussed more fully elsewhere in this issue, reveals the fact that in electrical apparatus, the power flows, not in the copper conductors as is generally supposed but in the space surrounding the conductors. While not strictly new, for it has been used for many years in radio work, this idea is somewhat startling and upon first thought may seem to conflict with the accepted theories. As Dr. Slepian pointed out, however, this conception when applied to an interpretation of phenomena in electric circuits is, in many ways, superior to the accepted theory that the power flows through the wires.

Now, it may seem strange that after 40 yr. or more of practice in electrical engineering, during which time the industry has grown from nothing to the greatest force civilization has ever known, we should find it convenient to change our conception of such a common phenomenon as power flow. Yet, to one who has studied the advances in electrical engineering during the past few years, it is not strange; it is, rather, to be expected.

During the past quarter of a century we have been forced to change our ideas of many things, not only in the realm of electrical science but in all the sciences. Some of our most cherished notions have been shattered by the revelations of modern physics and, in the electrical field, new discoveries have followed each other in such rapid succession that the electrical engineer of a few years ago, who has not kept up with modern developments, is severely handicapped. He is at a loss to know what it is all about.

Twenty years ago the electron was a dream—an interesting hypothesis; nothing to be taken seriously in working out problems in practical electrical engineering. Today, all this changed. We have not only proved the existence of the electron beyond any question of doubt but we have weighed it and have measured its electric charge with an accuracy far greater than that with which our grocer weighs out a pound of sugar. The electrons are known to be the ultimate building stones of the universe. There are only two material things in the universe—positive and negative electrons.

Since the activities of these electrons are at the base of all physical, chemical and life phenomena and since, in electrical engineering we are dealing directly with their properties, it is natural that the study of electricity should begin with the electron. Up to the present time, textbooks on electrical engineering have started in the middle and have given the electron little or no consideration. The textbook of the future will start out with a study of the electron and then by a series of logical steps will proceed to explain all electrical phenomena in terms of this fundamental unit. In that particular branch of electrical engineering concerned with "radio" phenomena this method of treatment has been used, to a certain extent, with considerable success.

With so remarkable an underlying unit, it is to be expected that many of our existing theories would prove incorrect. Take, for example, the flow of current in an electric circuit. In the usual or conventional sense, its direction is from the positive pole of the battery or generator to the negative. A study of vacuum tube phenomena, however, shows that the electrons which constitute the electric current, flow in just the reverse direction, that is, from negative to positive. Yet, for over 40 yr. we have been preaching and practicing the opposite!

So much for the electron. From another angle the correctness of some of the postulates in classical electromagnetic theory is being challenged. In the Maxwellian theory, the closed circuit is regarded as the fundamental electric circuit. It has been pointed out that a too rigid adherence to this closed circuit theory is not only misleading in many ways but sometimes leads us away from useful facts and relations. The proposal has been made, therefore, to consider the open circuit, that is, a unit length of a single straight conductor, as the fundamental circuit and the closed circuit of the Maxwell theory, a special case of the open circuit. This proposal has been the subject of much discussion and has met with considerable opposition. Regardless of many arguments to the contrary, the proposed theory has many points in its favor and has been particularly successful in explaining the "pinch" and "stretch" effect in electric furnace work.

This state of affairs in electrical science need cause no uneasiness. A theory or hypothesis is useful just as long as it serves a purpose; beyond that it is a hindrance. We are advancing. During the past 25 yr. we have learned more about the universe in which we live than we did in all the countless ages preceding. It is only natural, then, that some of our old theories should go by the board and new ones, or at least modifications of the old ones, be substituted.

Keeping Fit

How often do we hear the complaint "Oh, if we could only get the company to scrap this old plant and build a new one with modern equipment, we could really show some results." Who is it that does not prefer to work with new equipment? Used equipment is always looked upon with disfavor and few engineers would recommend its installation in a plant of which they are to have charge.

So rapid are the changes in power plant equipment, however, that in the regular course of continuous construction of a power plant covering a period of 4 or 5 yr. the last units installed in the plant are usually quite different from the initial units. The first units are by no means obsolete nor worn out but may lack some of the refinements incorporated in the later units. So, even new equipment does not retain its distinction of the "lastest model" more than a year or two at most.

What really is required of the engineer in charge is to improve plant operation by the application, so far as possible, of principles used in the latest equipment. Automatic control of feed water to the boiler, steam pressure, draft and water temperature have become standard practice in power plants, yet many are still without these refinements which can readily be applied in the oldest plants of the country. Some of the more recent developments, such as preheating air for combustion, extracting steam from turbines for feed water heating, reheating steam from high-pressure turbines for use in lower pressure units, are not so readily applicable in an old plant but, in many cases, a little study will reveal how advantage may be taken of even these in some plants by slight modifications in arrangements.

As a rule, practically all the modern improvements, with the exception of revolutionary changes in the principal equipment of the plant, are applicable at moderate expense in plants that are not completely obsolete or worn out. Power plant instruments of every description are applicable in old as well as new plants; modern furnaces and stokers can be built to serve old boilers; to change from steam to motor drive for auxiliaries is a matter of development which does not offer great difficulties; substituting mechanical handling of coal and ashes for the manual method is being done every day. We have only to visit some of the well-known old power plants of the country and observe the equipment there to realize that these plants have developed with the changing practices of the times and their records will show the results obtained are not far behind the newest plants. Keeping a plant in the running with the most modern is an engineering problem which rightly belongs to the engineer in charge of operation.

Hydraulic Engineers May Have to Study Astronomy

For some time we have been interested in the various reports about the weather that have appeared in the newspapers and general magazines, particularly as they apply to the rainfall conditions in various parts of the earth. Our interest was first aroused when we found in the 1925 report of the Hydraulic Power Committee of the N. E. L. A., issued last June, a discussion of methods used by hydrologists in analyzing and forecasting rainfall and of the bearing of such analyses on the water supply and consequently on the very basis of hydro-electric plant design and operation.

Reports of drought in some sections of the South and in some of the Northern States came in during the summer of 1925. Reports from the hydrographic office of the U. S. Navy indicate that the Humboldt current and the Japan current have changed their courses slightly, thus causing rain to fall in districts fromerly arid. Recently reports of severe rainfalls in Europe, especially in France, earthquake disturbances in the Middle West and along the Atlantic seaboard were noted. Several weeks ago another eruption of Mt. Vesuvius occurred.

When we turn to the Hydraulic Power Committee report, referred to above, we find some significant statements in regard to just such phenomena. One statement, made early in 1925 and credited to H. J. Browne, the hydrologist, was that the year 1925 would be a severe one throughout the world and that 1926-1927 might witness another year without a summer such as occurred in 1816. Mr. Browne ascribes these conditions to decreases in the sun's radiation caused by various solar disturbances, since all weather comes primarily from the translation into heat of that extremely small fraction of the Sun's radiation that impinges upon and penetrates the earth's atmosphere. A drop in solar radiation has occurred during the past few years and its effects are definitely measurable in the decreasing ocean temperatures. "One further element alone," said Mr. Browne, "is required to reproduce the weather of 1816; a violent volcanic eruption or a series of lesser ones but sufficient to throw into the upper air a huge volume of volcanic dust, to reduce the earth's average temperature to some 10 deg. F." It is to be remembered that these statements were published long before the recent heavy rainfalls, floods and volcanic eruptions in Europe, referred to above.

So it is evident, in checking up what was predicted with what actually happened, that there are some points of agreement and some points of disagreement. It is equally evident from the report that it is possible to forecast rainfall conditions for limited localities and to some extent for whole countries. More and more attention is being given to the subject and the attention paid to it by the N.E.L.A. Hydraulic Power Committee is significant. The fact remains that a study of weather conditions is of extreme importance to the hydraulic engineer. If it develops that these weather conditions are caused by solar disturbances, as present evidence seems to indicate, then the hydraulic engineer may be forced to become somewhat of an astronomer, in order to forecast his water supply over long periods.

Fundamental Knowledge Is Engineer's Foundation

Every now and then we get inquiries from engineers regarding books on engineering subjects and also on correspondence schools of engineering. It is always a pleasure to answer letters of this nature. Engineers who are seeking to better their conditions by broadening their knowledge can always be helped by reading books, provided they can do so understandingly. The same is also true of their attempts at learning through a correspondence course. Whether a man reads a book of his own selection or one supplied by the correspondence school, he must first have a knowledge of fundamentals which will enable him to understand the points involved.

Many textbooks on power plant practice and also the material offered in correspondence courses fail to emphasize the importance of elementary principles. This is particularly true in combustion engineering and thermodynamics. There are few private schools of combustion and many of the state universities offer extension courses in combustion and steam engineering. Power plant engineers seeking better positions are urged to avail themselves of these opportunities but are cautioned not to blindly rush into a course for which they are not prepared.

Almost every town in the country having a certified high school now offers night school courses and it is here that a power plant engineer whose earlier years denied him a high school education, should begin. No structure, physical or mental, can long endure without a solid foundation. Before attempting to study combustion or steam engineering, go to night school and learn the fundamentals of chemistry, physics and algebra.

Midwest Power Conference

JAN. 26 TO 29. IN THE FURNITURE CLUB ROOMS, 666 LAKE SHORE DRIVE, CHICAGO

PLANS HAVE GONE steadily forward and the final program, as offered by the committee representing the various engineering societies, shows a wealth of speakers of national reputation as engineers and executives and a range of subjects covering the entire field of power engineering.

Registration will open Tuesday morning, a nominal fee of $1 being charged to cover expenses of arrangement. The registration badge admits to all activities of the Conference except the dinner, also to the Power Show at all times during the week.

For the week, the program of sessions and papers is as follows:

Tuesday afternoon at 2:30. Address by Samuel Insull, "Some Comments on Power Development of the Mississippi Valley."

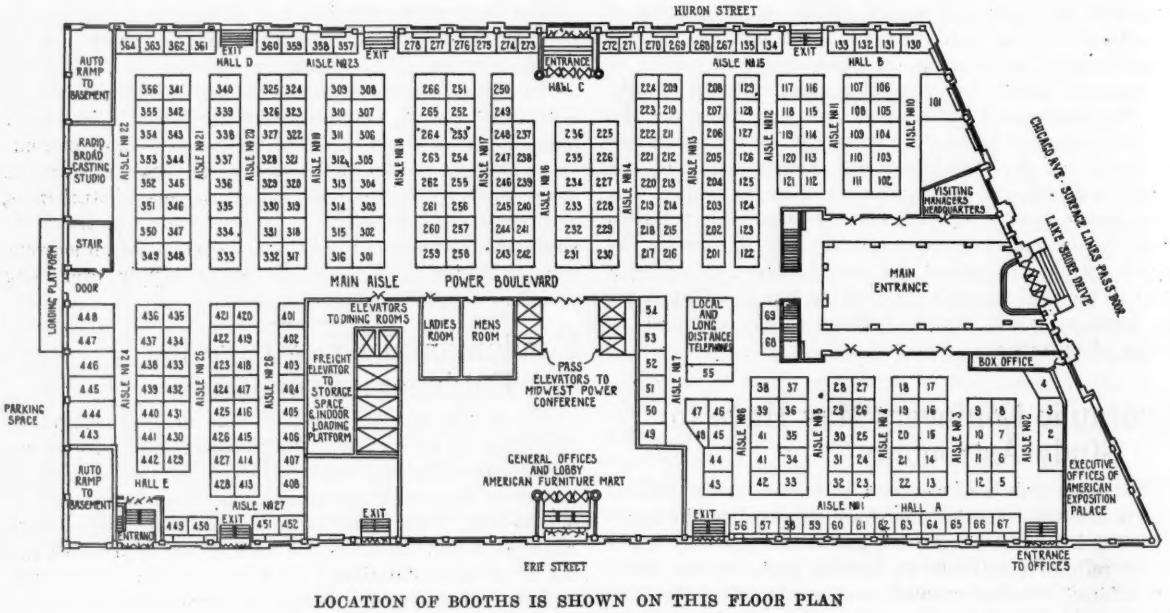
Wednesday morning at 10:00, papers by Daniel W. Mead on Water Power Resources of the U. S.; by H. Birchard Taylor on Changing Viewpoints in Hydraulic Turbine Practice; by L. F. Harza on Suggestions Regarding Hydraulic Plant Operation; and by R. F. Schuchardt on Super Power in the North Central States.

Wednesday afternoon at 2:00, papers by William S. Monroe on Electric Power Development in the Chicago District; by C. F. Hirshfeld on Present Practice in the Burning of Pulverized Fuel; by H. W. Brooks on By-Product Processing of Coal; and by Dr. R. E. Hall on Boiler Water Conditioning, with Special Reference to High Pressure and Corrosion.

Thursday morning at 10:00, papers by Paul L. Battey on Layout and Equipment of Industrial Power Plants; by G. B. Warren and J. H. Keenan on Testing Steam Turbine Nozzles by the Reaction Method; by G. C. Neff on Extension of Power Service to Rural Communities and by J. Paul Clayton on Purchased Power for Coal Mines in Illinois.

Thursday afternoon at 2:00 Inspection trips: 1. Bus trip to the Crawford Ave. Station by courtesy of the Commonwealth Edison Co. 2. Hawthorne Works of the Western Electric Co.; by Chicago Ave. surface line and Douglas Park branch of the Metropolitan elevated railroad; get off at Cicero station. 3. Plant of the Chicago Tribune and the Tribune Tower; within walking distance. 4. Underwriters Laboratories with tests of foam extinguisher for gasoline fires, sprinkler systems and oil burners; in walking distance.

Thursday evening at 7:00 dinner in the rooms of the Furniture Club of America, 666 Lake Shore Drive. Toastmaster, Charles Piez, Chairman of the Board, Link-Belt Co. Speakers, J. A. Emery, Vice Pres., Ford, Bacon & Davis, on The Broad Importance of Power Development. Gen. Charles Keller of Byllesby Engineering and Management Corp., Supervisor of Power during the World War, on Power Development as a Factor in National Preparedness. Tickets for the dinner $3. Tickets should be purchased early.



LOCATION OF BOOTHS IS SHOWN ON THIS FLOOR PLAN

Friday morning at 10:00 papers by Max Rotter on The Diesel Engine in the Industries; by Samuel M. Vauclain on The Diesel-Electric Locomotive and Its Future Possibilities; by Allen F. Brewer on The Economics of Oil Burning; and by H. H. Clark on Gas in Industry.

Friday afternoon at 2:00, Inspection Trip to the New Tractor Plant of the International Harvester Co. by surface lines. Grand Ave. to Western Ave., then south to 31st St.

Chicago stock yards at any time by South Side Elevated to Indiana and transfer to Stock Yards branch.

Chicago Ave. Pumping Station, admission by badge at any time; in walking distance.

Registration for trips to Crawford, Hawthorne and Harvester should be made 24 hr. ahead of starting time.

For the Ladies

Wednesday noon at 12:30 Luncheon, followed by bridge and five hundred at the Edgewater Beach Hotel. Take Northwestern Elevated to Edgewater Beach Station. Tickets $1.

Thursday afternoon at 2:30 visit to the Art Institute. Meet in the main lobby. Admittance free by asking for the Midwest Power Conference Party. After trip through the galleries, tea in the Club Room at 4:00.

Thursday evening. Theater Party to see Mrs. Samuel Insull in The School for Scandal, La Salle St. Theater. Tickets on sale at the registration booth up to Wednesday evening.

Friday morning at 11:00, trip through Marshall Fields. Assemble at the Information Bureau, 3rd floor.

Tickets and registration should be secured as early as possible. For Edgewater Beach by Tuesday evening; for the Art Institute by Wednesday noon; for the Theater by Wednesday evening; for Fields by Thursday afternoon at latest.

The opportunities for study, acquaintance and enjoyment at the Conference and the Power Show will be worth any effort necessary to attend.

Power Plants Need Modern Equipment

In the Chicago Power Show Will Be Found a Comprehensive Display of Such Equipment

Herewith is presented the arrangement of the exhibits at the Midwestern Engineering and Power Exposition. In itself, the directory proves that the best of equipment and methods for power plants will be demonstrated and plenty of time should be taken to give careful study to the displays in the various booths.

The section to the left of the main entrance is known as Hall A and contains booths 1 to 69; to the right is Hall B with booths 101 to 122; in the center of the Huron St. side is Hall C with booths 201 to 278; beyond this is Hall D with booths 301 to 364; and beyond the elevators is Hall E containing booths 401 to 454.

Opening of the show will be at noon on Tuesday, Jan. 26, in the main entrance lobby, with short addresses by prominent civic officials and engineers, followed by an inspection trip to exhibits.

The exhibit hall will be open daily from noon to 10:30 p. m., Jan. 26 to 30 and can be reached by Chicago Ave. cars which pass the door, by the Grand Ave. line 3 blocks south or by Michigan Ave. motor busses 4 blocks west.

The detail directory of exhibits by booths and firms follows:

Exhibits at the Midwestern Engineering and Power Exposition

Am. Soc. Mech. Engrs. 55

Aero Pulverizer Co. Unit pulverizer system and action of paddles, trash separator, and details of construction. 402-3
Representatives: W. W. Clinedinst and H. B. Baird.

Air Preheater Corpn. Ljungstrom air preheater, Howden compressors and forced draft equipment. Patent furnace fronts. 218
Representative: C. A. Jacobson.

Alberger Heater Co. Howard guided expansion joints. Alberger-Buffalo, copper-tube heaters. 220
Representative: E. A. Hahl.

Alexander Brothers. Running exhibit of Tentacular suction belt driving generator to demonstrate effectiveness and steadiness. Samples of belt to show special construction. 107
Representatives: H. G. Watson, R. R. Liggett and J. L. de Rabot.

Allen-Sherman-Hoff Co. Hydrojet system of ash handling with intermittent, high-velocity streams, ash gates, cast-iron bunkers and tile-lined hoppers. Operating model showing action of system. 438-39
Representatives: F. B. Allen, J. Stokoe and H. R. N. Johnson.

Allis-Chalmers Co. Steam and hydraulic turbines, steam and gas engines, electrical machinery, transmission equipments, special equipment and machinery for mining, metallurgical, cement and crushing plants, saw and flour mills. 256

American Arch Co. Suspended renewable arches for furnaces. 358-59
Representatives: H. A. Mannshardt, J. A. Lodwick and F. D. Hazen.

American Asphalt Paint Co. Moving pictures of asphalt mining and manufacture of asphalt paint with descriptive talk and explanation of the pictures. 39
Representatives: Gordon White, H. R. Harwood, J. H. Heist and J. F. Junk.

American District Steam Co. Expansion joints, duplex sleeve, for high-pressure packless diaphragm, guided and anchor and service types for standard pressures. Underground steam and return line construction, steam flow and condensation meters, traps, water heaters, heating specialties and wood casing for underground lines. 115
Representatives: W. A. Schulmeister and C. R. Frantz.

American Electric Motors, Inc. Electric motors and equipment. 222

American Pulverizer Co. Ring coal crusher for reducing run-of-mine coal to stoker and pulverizer sizes. 446
Representative: Paul S. Knittel.

American Steam Pump Co. American Marsh Centrifugal and reciprocating feed-water, service, air and condensate pumps, jet condensers and hydraulic pressure pumps. 425
Representative: E. H. Davis.

Andale Engineering Co. Duplex oil and water strainers and sectioned models. 211-12
Representatives: D. Raymond McNeal, James T. Gordon and S. Wolff.

Andrews-Bradshaw Co. Tracyfier (steam purifier) in a complete full-size working model showing operation to remove fog, mist and other forms of boiler water from steam. 273-74
Representatives: Grant D. Bradshaw, O. R. Mc Bride, G. M. Kirkpatrick and J. Lucien Jones.

Armstrong Machine Works. Various sizes of steam traps, sectioned models to show construction, glass model trap in operation under steam to demonstrate effectiveness of action. 337
Representatives: L. D. Goff, O. E. Ulrich, Mr. White, Mr. Olson, Mr. Sprenkle and Mr. Kemp.

Atlantic Metal Hose Co. 323

Atwood & Morrill Co. Heavy duty valves and construction for high temperatures and pressures and for bleeder heating. Damper regulation. 446
Representative: C. P. Atwood, Treas.

Automatic Primer Co. Apco primer for centrifugal pumps. 57

Babcock & Wilcox Co. 5-6-11-12

Bailey Meter Co. Meter control equipment for automatic boiler operation, running to show the method of control. Bailey furnace wall for low maintenance cost and high ratings. Pulverized coal feeder and meter to give uniform rate of feeding from bin to burner. 5-6-7-8
Representatives: E. G. Bailey, Pres., R. S. Coffin, Vice Pres., W. E. East, F. C. Brandt, M. Greenberg, L. W. Heller, R. Shellenberger, R. V. Knapp and W. J. Reeder.

Barco Mfg. Co. Lubricated plug valves, flexible ball joints and Argyle-Titan electric drills. 29
Representatives: C. L. Mellor, Vice Pres., J. T. Ross, C. O. Jenista and F. N. Bard.

BARRETT-CHRISTIE Co. Steam traps, water heaters, shovels and scoops, bearing metal, packings and gage glasses. 338
Representatives: Harry Barrett, Pres., J. G. Christie, Secy. & Treas., Mr. White, Mr. Olson and Mr. Sprenkle.

BARTLETT-HAYWARD Co. Fast all-metal, flexible, positively-lubricated shaft couplings, and photographs of special installations. 211-12
Representatives: Gustave Fast, Hugh Benet, H. W. Calder and S. Wolff.

THE BAYER Co. Mechanical soot blowers, details of construction and control. 448
Representatives: C. P. Kelly, Ernest E. Lee, J. L. Higgins and F. E. Oswald.

R. H. BEAUMONT Co. BEAUMONT MFG. Co. Model in operation of centralized coal handling system for boiler house. Cable drag scraper system for storing and reclaiming coal. Copper steel ash hopper and both small and power-operated ash gates. 341-44
Representatives: R. H. Beaumont, Pres., H. V. Schiefer and J. A. Beck.

BETHLEHEM SHIPBUILDING CORPN., LTD. Oil-burning system, air compressors, direct and turbine-driven pumps, feed heaters, evaporators and deaeration system. 110-111
Representatives: G. A. Worn, Sales Dept., New York Office: Roy Ewertz, Cleveland Office, Irwin D. Groak, Sales Representative in charge of Chicago Office, and three or four assistants.

BETHLEHEM STEEL Co. Full size pulverizing plant for coal and other minerals. Diesel engines 102-103
Representatives: G. W. Struble, in charge of Machinery, Ordnance and Power Sales: J. P. Madden, Machinery Sales Engineer; W. F. Price, Machinery Sales. In charge of both exhibits, George A. Richardson, Manager, Technical Publicity Dept.

BOSTON GEAR WORKS SALES Co. Speed-reduction units. Silent chain drives. Special gears. 417-18
Representatives: H. H. Kerr, H. C. Woodsum, M. T. Schumb and H. Muller.

BOTFIELD REFRACTORIES Co. Special forms of fire brick construction, including air-set arch. Applications of Adamant high-temperature fire-brick cement. 17
Representatives: H. F. Kreig, Axel H. Engstrom, L. B. Botfield and W. B. Smith.

BOYLSTON STEAM SPECIALTY Co. Steam traps, regulating and back-pressure valves, tank valves, temperature controllers, strainers and other steam specialties. 421
Representatives: John Boylston, Harry J. Richter and John P. Kieley.

BRISTOL Co. Indicating and recording gages, thermometers, pyrometers and water level gages. 104
Representatives: L. G. Bean, H. A. Graf, S. W. Case and H. W. Moss.

BROWN INSTRUMENT Co. Electric Co_2 meter and flue-gas pyrometer, recording, indicating and portable pyrometers, indicating and recording long-distance thermometers, electric tachometers, liquid level recorder, vacuum, draft and pressure gages. 128
Representatives: M. M. Watkins, C. L. Saunders, R. W. Conwell, John R. Green, O. P. Kossatz and E. Robinson.

BRUNSWICK-KROESCHELL Co. Ice machines, boiler construction and details and photographs of plants and factories for building boilers and refrigerating machinery. 30
Representatives: R. O. Butz, Vice Pres., A. H. Goelz, O. A. Rochlitz, J. Corydon, Fred Lautenschlager, Carl Kroeschell, H. A. Stade, H. V. Hess, Robert A. Kroeschell, Secy., William B. Rorison, Paul Kroeschell and W. G. Cobb.

BUFFALO FORGE Co. Ventilating and special induced draft fans, boiler feed pumps, Breezo-Fin heaters and Carrier air washer. 14-16
Representatives: C. C. Cheyney, L. D. Emmert and O. S. Ryan.

BUILDERS IRON FOUNDRY. Venturi meters, venturi tubes, type M register-indicator-recorder in operation, indicator-recorder, manometer and venturi nozzle for steam. 62
Representatives: W. D. Hess and G. H. Jewell.

BURKE ENGINEERING Co. Traveling-grate stoker, fuel-saving, smoke preventative furnace and U. S. rocking grate. 347-48
Representatives: E. W. Ritter, Pres., Walter T. Ritter, Treas., J. B. Grigg, S. L. Arson and R. M. Leddick.

CARR FASTENER Co. Dot system of pressure lubrication with fittings, hand guns, hand and power operated compressors and tanks. 18
Representatives: P. K. Niven, C. Towner, A. W. Smith, A. H. Taylor, R. C. Smith and Fred Jones.

CARRICK ENGINEERING Co. Master-control system of furnace regulation demonstrated by glass inclosed working model. 261
Representatives: G. S. Carrick, John H. Hollmeyer, J. W. Murphy, J. F. Volbrecht, Joseph E. Walsh, J. J. Neville, R. Knotek, P. Armstrong, John Erwood.

CASEY-HEDGES Co. Water-tube boilers, details of construction, systems of setting and baffling, return tubular and steel cased boilers. 431
Representatives: L. H. McGowan and W. A. Day.

A. W. CASH Co. Craig system of automatic combination control with master controller for draft fans, stoker engines and stack dampers and individual control of blast dampers in wind boxes. Pressure regulating and reducing valves, relief valves, pump governors. 251
Representatives: V. A. McKechnie and C. W. Court.

CENTRIFIX CORPN. Steam purifying system. 19
Representatives: C. G. Hawley, L. C. Kerney, E. O. Mueller, O. P. Warner and K. H. Talbot.

CHAPMAN VALVE MFG. Co. Chrome nickel steel fittings and valves for high pressures. Remote control system with visible signals for open, closed and being operated conditions. 347-48
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Representatives: G. A. Strom, G. C. Smith, H. N. Parsons, C. T. Olson, E. P. Schmidt, M. E. Monk, C. V. Johnson, H. R. Higgins and F. R. Schubert.

STRONG SCOTT MFG. CO. Unipulvo pulverizing and coal burning equipment. 58B
Representatives: A. W. Strong, Pres. and H. G. Lykken.

B. F. STURTEVANT CO. Turbine and Turbovane fans for forced and induced draft, air preheaters, ventilating fans and air washing equipment. Lead-coated economizer. Cindervane fan. 422-3-4
Representatives: F. Herlan, Vice-Pres., P. C. Ekblom, F. C. Dawson, A. B. Osgood and H. B. Roarke.

THE SUPERHEATER CO. Elesco superheater elements for 1500-hp. boilers, showing forged return bend for joining pipe lengths and ball and clamp joints to headers. Photographs of boilers showing location of superheaters for various types. 259-60
Representatives: R. M. Gates, B. N. Broido, R. S. Cooper, A. H. Charles Dally, R. L. Ehmann and L. H. A. Weaver.

W. O. & M. W. TALCOTT, INC. Belt fasteners, belt hooks, clinch fasteners and plate and rivet inserted fasteners. 322
Representatives: W. O. Talcott, Pres., and M. W. Talcott, Vice-Pres. and Sec'y.

TECHNO SERVICE CORP'N. 447

TIMKEN ROLLER BEARING CO. Model of steel mill which shows steps in producing Timken bearings. Details of improved bearing, rolls cone and cage. 101-2
Representatives: L. M. Klinedinst, W. B. Moore, G. D. Thewlis, Carter Miller, F. J. Lemper and F. N. G. Kranich.

TROY ENGINE & MACHINE CO. Details of its engine construction and of the lubricating system used. 221
Representatives: John H. Hopp and J. B. Patterson.

UEHLING INSTRUMENT CO. Waste meter for indicating and recording loss in flue gases. Combined barometers and vacuum recorder. 447
Representatives: Ernest E. Lee, J. L. Higgins, J. L. Mayer, F. E. Oswald and C. J. Schmid

UNION IRON WORKS. Installations and details of horizontal long-drum and cross-drum water-tube boilers; also of vertical bent-tube type. Universal return flue, fire-tube boiler. 308
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VASTINE SALES CORP. Air cooled furnace fire observation device. 325
Representatives: C. H. Samuelson, J. W. Himmelsbach, Geo. M. Vastine and R. P. Vastine.

VULCAN SOOT CLEANER CO. Valve operating cleaner head with integral, self-grinding disc valve, the element and valve operated by a single control. Ratchet operating head giving step-by-step movement. Heat-resisting soot cleaner elements. 346
Representatives: F. W. Linaker, Vice-Pres., Mr. Burnham, Mr. Bland and Mr. Lindsey.

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Representatives: Chas. W. Parker, Vice-Pres., John E. Miller, T. M. Meek, E. L. Gundlach, Frank H. Waite and George W. Davey.

WALSH & WEIDNER BOILER CO. Seamless forged steel sectional boiler headers, section of 54-in. steam drum for 425 lb. pressure, materials and method for baffling, drawings of settings. 350
Representative: M. D. Kizer.

WALSH FIRE CLAY PRODUCTS CO. Firebrick and furnace linings. 25
Representatives: Chas. W. Parker, Vice-Pres., John E. Miller, T. M. Meek and E. L. Gundlach.

WALWORTH CO. Sigma steel valves and fittings for high pressures and temperatures. Special features in steel casting processes and X-rays of casting defects. 267-70
Representatives: J. M. Olmstead, F. H. Krahn, H. R. Willard, J. J. Harman, F. W. Duemler and W. H. Weber.

WARREN WEBSTER & CO. Modulation system of steam heating demonstrated by a working model with action of essential parts visible under glass pipe. 275-6
Representatives: William H. Chenoweth, H. G. Thomas, I. N. Soper, F. W. Wren, R. G. Rosenbach, L. P. Lang, B. Harter, H. Schlaeger, M. A. Norman and E. H. Beling.

WESTERN UNION TELEGRAPH CO. Station for telephone and telegraph messages. 51

WESTINGHOUSE ELECTRIC & MFG. CO. Steam turbines for generator and mechanical drive, steam-jet air ejectors, Auto valve lightning arresters, equipment for reconditioning transformer and circuit breaker oils, meters, switches and lighting equipment. 201-2-3-4
Representative: L. M. Gumm.

C. H. WHEELER MFG. CO. Rado-jet air pumps and sectioned model showing construction and operation. Inter and after condenser for closed feed water systems. Photos of dualbank condensers and of 70,000 sq. ft. condenser as assembled at factory and as installed. 105-6
Representatives: C. H. Wheeler, Jr., Vice-Pres., G. L. Kothny, J. Dobson and Frank Wheeler.

WHEELER CONDENSER & ENGINEERING CO. Condensers air pumps, cooling towers, hotwell pumps, evaporators, bleed heaters, expansion joints, oil heaters, centrifugal pumps, steam jet pumps and other similar equipment. 226-27
Representatives: E. R. Goodrich, O. E. Anderson, Mr. Chapin, V. T. Price and R. G. Backus.

WITHERUP CORK PACKING CO. 323

WOLFF & CO. Andale strainers, grease extractors, coolers and heat exchangers. Fast's flexible couplings, Cleveland speed reduction units, rear axle drive and worm and gear sets. 211-12

WRIGHT-AUSTIN CO. Extra heavy water gauge, weighted metal whistle valve and Brownie low-water signal tri-cock safety alarm, water columns with Monel small boilers. 61
Representatives: C. Burt, Vice-Pres. and H. R. Patterson.

YARNALL-WARING CO. V-notch meters for recording and integrating flood flow, balanced blowoff valves and spray nozzles. 277-8
Representatives: H. J. Moyer, W. G. Heacock, S. D. Barr, Jos. Kildare and Chas. Thompson.

YEOMANS BROS. CO. 447-48

Increased Electrification Has Cut Coal Consumption

IN THE thirteenth annual report of the Secretary of Commerce, the elimination of waste through enlarged electrification is discussed by Paul S. Clapp, special Assistant to Secretary Hoover. He states that during the past 5 yr. there has been a notable advance in the electrification of the country and in the generation and distribution of power. This is being accomplished not only with an enormous saving in fuel but with large increases in productivity, reduction of physical effort and labor, and added comfort in the home. Since 1920 long strides forward have been taken in the development of widespread electrical power systems, which are increasingly becoming the enormous reservoirs of mobile and reliable power for all purposes, upon which in such lrage measure our national progress depends.

With the development of long-distance transmission and its sequence, the production of power upon a large scale in more economical plants at most advantageous points, is having a far-reaching influence.

Our electrical generating capacity increased from 14,280,000 kw. in 1920 to over 23,000,000 kw. in 1925, an increase of 60 per cent. This has been effected principally in large efficient units concentrated in carefully operated central plants, with gradual elimination of wasteful smaller plants. At the same time the development of water powers connected to electrical systems has been particularly active. Of the total of 8,300,000 hp. now developed and connected to these systems, 2,500,000 hp., or 30 per cent, has been set to work in this period.

Interconnection of power plants, hydro and steam, has rapidly progressed, enabling maximum utilization of each with large economies in power production and distribution. Factory steam plants are being replaced with electrical power, the increased industrial load during the day being supplied from the same equipment as the night load of cities. The capital invested in idle or underloaded equipment has been effectively reduced. Water powers formerly too far removed from the market are now being developed and put to work. The steadily increasing base load upon large economical central plants and the shift from small electrical or industrial plants has resulted in great savings in fuel. The consumption of coal or its equivalent by electrical plants has been decreased from 3.2 lb. per kw. as the average required in 1919 to 2.2 lb. in 1924, a total saving in this period of over 50,000,000 t. To this can be added the saving of some 6,000,000 t. from the water power put into operation, making a total of 56,000,000 t. saved.

Power cost has been maintained at pre-war levels, the large economies in production and distribution offsetting the rise in labor and material costs.

In industry there have been large increases in the power applied, and in the shift toward electrification the source of supply increasingly becoming the interconnected systems. In 1919, 55 per cent of the total primary power in factories was applied electrically; this has increased to 70 per cent. Between 1919 and 1923 power used in industry increased from 29,300,000 to 33,000,000 hp.

Gas and Electric Display at the Chicago Power Show

THE GAS and electric properties in Chicago and adjacent territory will occupy booths Nos. 228 to 233 which are situated on Power Boulevard.

The gas exhibit will be backed by a scenic panorama, indicating the many manufacturing activities in and around Chicago, and the important part which gas plays in industrial economy. This panorama will be artistically illuminated by a system of changing lights.

Two small models placed on either side will also form part of the exhibit. One of these shows the "Village Blacksmith" forge and bellows and the other, a modern forge where gas is used exclusively.

Folders and other literature on the subject of factory heat treatments will be available for everyone interested in the subject.

In the Electric Exhibit, three large illuminated maps will be displayed. These ilustrate the great development in the transmission of electric energy and in the interconnection of systems, which has been taking place in the States of Wisconsin, Illinois, Indiana and Kentucky.

A study of these maps will disclose the highly developed inter-connection between the water-powers of Wisconsin, the great steam stations in the Chicago District, extending south through the entire State of Indiana, and over into Kentucky, connecting up with the water-power development in the latter State. They also give a striking picture of the great pool of power—the largest in the world—in the Chicago district, through the interconection by 132,000-v. super power transmission lines of the systems of the Public Service Co. of Northern Illinois, the Commonwealth Edison Co. and the Midland Utilities Co., the aggregate capacity of which, on January 1,1926, equaled 1,100,000 kw.

The holdings of the various companies within the Insull group of utilities may be readily distinguished, as a different color has been used in the outlining of each of the systems, and the holdings outside of the Insull interests are shown in yellow. Plain stars indicate the locations of the steam generating stations, and each hydro-station is represented by a start in a circle. The super-power (high-voltage) transmission is indicated by heavy broken lines and the lower voltage by smaller, continuous lines.

These maps should prove to be unusually interesting and instructive, as they clearly indicate the trend of the times in our industry.

Distortion Test of a 4-In. Sigma Steel Flanged Tee

AS IS well known, the tendency of the times is toward increased working pressures and superheat requirements in power plant installations and increased working temperatures and pressures in oil refinery processes. Walworth Co., having in mind this trend and foreseeing the necessity for fittings and valves capable of withstanding high-temperature requirements, some time ago made an exhaustive series of x-ray studies of steel castings at the Watertown Arsenal. The net result of this long period of research work is a new line of steel fittings and valves known by the name "Walworth Sigma." This embraces a line for 250-400-600-900 lb. working steam pressures at total temperatures of 750 deg. F. which conforms to the Tentative Standards of the American Engineering Standards Committee.

In order to demonstrate by actual tests the elasticity and strength of Walworth Sigma Steel, a test was made of a 400 lb. working steam pressure Sigma steel flanged tee. The fitting was first given a hydrostatic pressure test of 2500 lb. per sq. in., a little over six times the rated working steam pressure, at which pressure it was absolutely tight.

It was then connected to two pieces of 4-in. double extra heavy pipe, supported on 18 ft. centers, and loaded with two weights of 3714 lb. each. The first weight produced a deflection of $2\frac{9}{16}$ in. as shown in Fig. 1. In this figure, the first weight is supported entirely on the fittings, the second weight being supported by the overhead crane. The second weight was then gradually lowered until the flange of the fitting rested on the floor, producing a total deflection of $27\frac{1}{16}$ in., as shown in Fig. 2. The elasticity of the fitting is shown by the uniformity of the bend in the fitting and in the pipe adjacent to it. This flexibility reduced the localized strain in the flange joint bolting material, and thus increased the strength of the structure as a whole.

When the weights were removed the structure sprang back a distance of $4\frac{3}{16}$ in., leaving a total permanent deflection of $22\frac{7}{8}$ in. The fitting was then removed and again tested perfectly tight at 2500 lb. hydrostatic pressure. This test demonstrates conclusively that the design of the fitting was satisfactory, that the casting was sound throughout, containing no injurious interior defects, and that it was properly heat-treated.

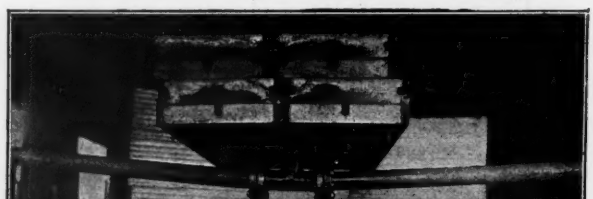


FIG. 1. FIRST WEIGHT DEFLECTED PIPE AND FITTING $2\frac{9}{16}$ IN.

FIG. 2. TOTAL LOAD OF 7428 LB. PRODUCED THIS RESULT

Detroit Double Retort Side Cleaning Stoker

FOR the smaller boiler the mechanically driven single retort stoker has accomplished splendid results, but for the medium size boiler of 300 hp. and larger, where multiple retort cleaning stokers are normally adaptable but cannot be installed for lack of sufficient space or other conditions, the double retort stoker has been developed by the Detroit Stoker Co. of Detroit, Mich. With this later design, two retorts do the work which formerly had to be done by one. Experience in various parts of the country has shown this machine to be successful in operation. One of the characteristics of the double retort stoker is that the normal speed of the coal feeding mechanism is greatly reduced. Slow movement of fuel insures better ignition, complete combustion, and high capacities. Complete underfeed action is obtained, with larger active grate area, as the double retort stoker is designed for heavy duty, and it is capable of being driven at continuous high ratings. At the same time it will develop high efficiencies with light loads. In practice this stoker has been found to be flexible. It can be brought quickly from a banked fire condition to full rating.

With this stoker a basement or tunnel is not required, and the ashes can be removed at the front of the boiler directly onto the boiler room floor, and the bottom of the ash pits can often be placed at the level of the boiler room floor. Comparatively little excavation or concrete work is

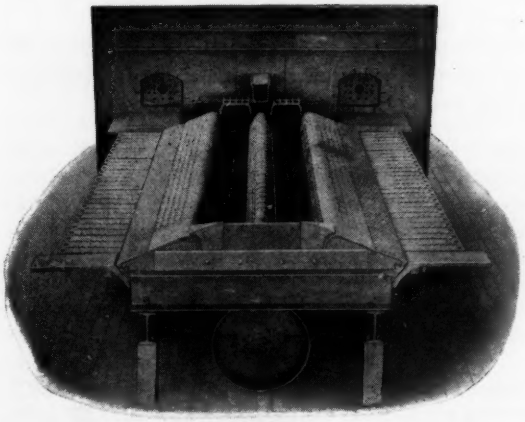


FIG. 1. REAR VIEW DETROIT DOUBLE RETORT STOKER

required to effect an installation under boilers previously in service.

Extending from the sides of the retorts are heavy grates inclined downward toward the side walls. At the end of these grates are located the dumping sections convenient to operate from the front of the stoker. A central air chamber is provided below the retorts. Numerous openings in the tuyeres are arranged to distribute the air evenly

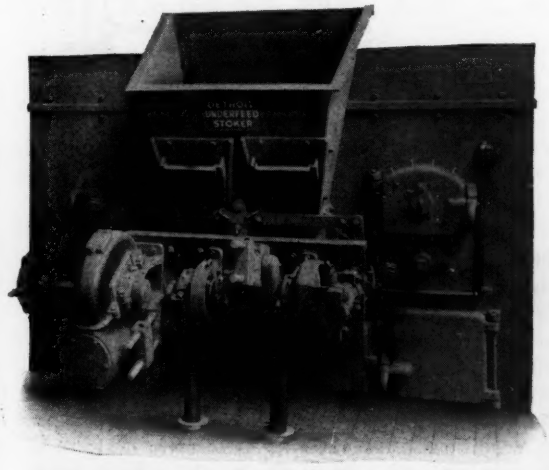


FIG. 2. FRONT VIEW SHOWING MECHANICAL DRIVE

throughout the entire fuel bed under comparatively low air pressure. A damper is provided for regulating the amount of air entering the air chamber.

Dump plates are of the grate bar type of construction with air ports. A damper is provided between each ash pit and the air chamber so that air under slight pressure can be admitted to the dump plates to burn completely the combustible in the ash before dumping.

Flow of the coal in each retort is under independent control. Fuel is delivered below the fire uniformly throughout the entire length of both retorts, thus providing complete underfeed action. For each retort, separate adjustments are provided governing the length of travel of each ram which can be regulated from full stroke to no stroke as well as the stroke of the auxiliary pusher bar. A further adjustment provides control of the rate of flow of the fuel to the dumps on the side.

Sandstone Rapids Plant Nearing Completion

THE SANDSTONE Rapids hydro-electric plant of the Wisconsin Public Service Corporation is nearing completion according to announcement by J. P. Pulliam, vice president and general manager. The capacity of the new plant is 5000 hp.

This plant will use the waters of the Peshtigo River for the sixth time. Plants are already in service at High Falls, Johnson Falls, Potato Rapids, Cauldron Falls and Peshtigo. The Sandstone Rapids plant is approximately 8 mi. below the High Falls plant, and utilizes a head of 45 ft. The total fall used by all the plants on the Peshtigo River is more than 300 ft.

High Falls, the oldest of the power developments on the Peshtigo, is the master station for this group of plants, the other plants being operated automatically. The automatic control not only takes care of electrical operation, but also handles the flow of water through the system.

Wisconsin Public Service Corporation, which supplies utility services in Green Bay, Oshkosh, Manitowoc, Sheboygan and Marinette, Wisconsin; Menominee, Mich., and about seventy-five other communities, was acquired by the Byllesby interests in July, 1925.

Material at 1500 Deg. Handled by Conveyor System

SUCH highly heated material brings special conditions that ordinarily do not have to be considered. But, at the Painesville, Ohio, plant of the Standard Portland Cement Co., hot cement clinker at 1500 deg. F. is dis-

PARALLEL SCREW CONVEYORS ARE USED TO HANDLE CEMENT CLINKER AT 1500 DEG. F.

charged from the kilns directly into four Stearns screw conveyors which operate in parallel as shown in the illustration. Three are 60 ft. long, the fourth 65 ft., all discharging into a screw cross-conveyor, running at right angles,

which carries the clinker to a centrifugal pump, discharging in turn to the coolers.

The high temperature necessitated special provision for expansion and unusually rigid support of shafts and flights to avoid warping and distortion.

All five conveyors are driven by the one motor, the four in parallel through bevel gears and the cross-conveyor by a speed reducer and chain. Each parallel conveyor has a jaw clutch cast integral with its bevel gear so that it can be cut in and out independently.

Location of the cross-conveyor is in a concrete trough built into the floor, which makes it possible to anchor the countershaft. By making the bearings of the parallel conveyors integral with those of the countershaft, the drive ends of those conveyors are also anchored firmly in alinement.

Screws of all conveyors are of steel plate 10 in. diameter and ⅜ in. thick, the troughs of $\frac{3}{16}$-in. plate with cast-iron feet riveted on and set on ½-in. plates, which are anchored to concrete piers. The plates have cast-iron guides bolted on, which allows the troughs to slide as they expand and contract, yet maintains alinement. To allow for expansion of the screw, it is cut back 3 in. from the hangers, the allowance for expansion of the screws being 2½ in. and for troughs, 5 in.

Tops of the troughs are covered with steel plate, flanged over along the sides, the flanges fitting into channel bars riveted along the sides of the troughs, and the joint being sealed by a sand filling. Hanger bearings are of chilled iron with main shaft bearings bronze-bushed.

This special installation was designed and installed by the Stearns Conveyor Co. of Cleveland, Ohio, and is one of many which that company has put in to meet unusual conditions.

Regulator Employs Mercury Column Control

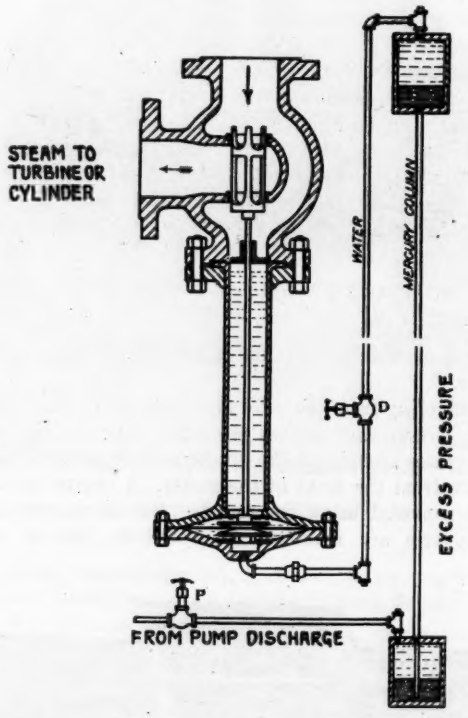
TO MAINTAIN in the boiler feed line a constant excess of water pressure above steam pressure, the Mercon excess pressure regulator, applicable to both steam-driven and motor-driven boiler feed pumps, employs the weight of a mercury column to balance the excess pressure that may be desired. The accompanying illustration shows the Mercon regulator as applied to a steam-driven pump. In this case it is installed in the main steam line to the pump, thus controlling the pump speed.

The amount of excess or differential pressure depends on the height of the mercury column, which is 2 in. for each pound of differential pressure required. If steam pressure at the valve is 300 lb. and an excess of 25 lb. is required at the pump discharge, the mercury column would be made 50 in., or 4 ft. 2 in., high. When the feed water pressure transmitted to the lower mercury receiver reaches 325 lb. the pressure in the upper pot and below the diaphragm is 300 lb. on account of the mercury counter pressure of 25 lb. The diaphragm is then balanced between 300 lb. steam pressure above and 300 lb. water pressure below.

Any increase in steam pressure above 300 lb. will now force the diaphragm down, opening the valve, and speeding up the pump until the feed water pressure is again 25 lb. above the increased steam pressure. If the feed water pressure starts to drop, the pressure under the diaphragm will decrease, the diaphragm will move down and the steam supply and pump speed will be increased until the water pressure is up to the required differential pressure.

In applying the Mercon excess pressure regulator to a motor-driven boiler feed pump, the valve is placed in the pump discharge line, the top mercury reservoir is connected to the main steam line and the bottom mercury reservoir to the under side of the diaphragm.

In adapting the Mercon regulator as a constant reduced pressure regulator, the mercury column balances the reduced pressure desired.



MERCURY COLUMN BALANCES EXCESS PRESSURES ON BOILER FEED LINE

The Mercon regulator is made by D. H. Skeen & Co., Chicago, Ill., to meet the varying conditions of each installation and is not a stock regulator. Valve bodies can be supplied in cast, forged or semi-steel or in bronze. Discs are of solid bronze or monel metal and of the double deck piston type. Sleeves are usually of unlike metal, monel in bronze being the usual combination and the outer sleeve being screwed in place. Ports can be of any shape demanded by conditions. The water leg is of extra heavy steel pipe or tube, the end next to the regulator body being Van Stoned and the other end being screwed against the shoulder in the diaphragm chamber. A loose fitting baffle around the stem at the top of the chamber is provided to stop sediment and the water leg is designed long enough so that the water in the chamber is always cool. The diaphragm chamber is of cast or semi-steel, and a sheet rubber diaphragm is used in most cases, although special diaphragms are supplied for oil and corrosive gases. Water and mercury columns are of small diameter steel pipe supplied by the customer; the closed mercury reservoirs are of steel pipe with the ends welded on.

New England Co. Plans Expansion

STOCKHOLDERS of the New England Co. have approved a plan for $20,000,000 enlargement of the company through agreement of the company with the International Securities Company, F. L. Carlisle & Co. which is affiliated with the Power Corporation of New York, and Stone & Webster, Inc. of Boston. Control over merged hydro-electric power interests in New England passes to an enlarged organization by this agreement.

The $20,000,000 provides for expansion into new territory. With the entrance of Stone & Webster, Inc., into the combine, the Edison Electric Illuminating Co. becomes interested to the extent of $1,000,000. Stone & Webster, Inc., has agreed to purchase 140,000 of the 400,000 new shares to be issued, the International Securities Co. takes 86,667 shares. This company being affiliated with the International Power Co. which has extensive power developments and water rights, the Power Corporation of New York takes 173,333 shares bringing the F. L. Carlisle & Co. interests into the New England field.

The New England Co., whose name may be changed to the New England Power System, is a holding company controlling by investment the New England Power Co., the Connecticut River Power Co., the Rhode Island Power Transmission Co., the Bellows Falls Power Co., the Fall Mountain Electric Co., the Bellows Falls Canal Co., and the Bellows Falls Electric Co. Its Davis Bridge reservoir has the largest earth dam in this country.

One result which is expected to come out of the merger is the larger exchange of power between New England and the New York and New Jersey companies. Lower operating costs and improved service is expected as a result of the merger.

N. Y. Chapter No. 2, N. A. P. R. E. Elects Officers

ANOTHER interesting evening was enjoyed December 10, 1925, by the members and guests of N. Y. Chapter No. 2, N. A. P. R. E. at the new meeting place, Cafe Boulevard, Continental Hotel, Broadway and 41st Street, New York.

First vice-president G. Savarese called the assembly to order at 8:00 p. m., to lose no time. After the roll call, Secretary Wm. S. Arvidson read the minutes of the November meeting. A. F. Miller read the treasurer's report. It showed expenditures made, $416.50; cash on hand $39.19 (same as A. S. R. E.) and $126 in dues outstanding. According to constitution, this Chapter meets on the second Thursday evening of each month. As everybody, guests included, is free to attend, no special invitations are sent out.

It was decided to make the fiscal year agree with the calendar year. Election of officers was therefore held, so these could start functioning at once. Accordingly the following officers were nominated and elected unanimously:

President, G. Savarese; First Vice-President, J. R. Bernd; Second Vice-President, L. K. Wright; Treasurer, Frank J. Malone; Secretary, Wm. S. Arvidson; Technical Secretary, Charles H. Herter; Chairman of Education Committee, Halbert P. Hill; Directors: J. Jacobs, E. Hatch, John Reiman; Sergeant-at-Arms, Wm. Vecchio.

In appreciation of work done gratis for Chapter No. 2, Charles H. Herter was unanimously elected honorary member.

Mr. Arvidson recommended fixing a program now for the next three meetings. He offered to handle himself the subject of Engine Room Records, January 14, 1926; L. K. Wright agreed to talk on Small Refrigerating Machines, February 11, while Mr. Herter promised to arrange, for March 11, 1926, an instructive welding session, with moving picture film, specimen pipe jobs and lecture by experts of the Oxweld Acetylene Co. of 30 E. 42nd Street, New York.

A. I. E. E. Midwinter Convention Will Have Many Papers of Interest

AS USUAL the Midwinter Convention of the American Institute of Electrical Engineers at New York promises to be full of interest, not only from a technical standpoint but also from a social standpoint. This year the convention will be held in the Engineering Societies Bldg., New York City from February 8-11.

Among the technical subjects to be discussed are transmission stability, protective and control systems, bus and steel-work construction, electrical machinery, measurements, insulation and dielectric absorption, electromagnetism and electrophysics, communication and sound reproduction, and furnace-resistor design.

In the social part of the program there will be an informal smoker on Tuesday evening, February 9, at the Hotel Astor. Some interesting entertainers will add to the pleasure of this evening.

The dinner-dance on Wednesday evening promises to be even better than the dinner-dances of the past few years, which always have been most heartily enjoyed. This event will be held at the Hotel Astor and a Paul Whiteman orchestra will furnish the music. This fortunate combination is an absolute guarantee of an excellent dinner, fine music and very enjoyable dancing.

On Thursday evening an address will be given by a prominent speaker.

New York, of course, offers a limitless variety of possible inspection trips and the trips being arranged will be most instructive. Among the places to be visited will be the new Holland Tunnel (the vehicular tunnel under the Hudson River), Broadcasting Station WEAF of the American Telephone and Telegraph Co., the Edison Lighting Institute of the Edison Lamp Works, the Loening Airplane Factory, Kearny Power Station of the Public Service Electric Power Co., Hudson Avenue Station of the Brooklyn Edison Co., Hell Gate and Sherman Creek Stations of the United Electric Light and Power Co., the Bell Telephone Laboratories and a machine-switching central telephone office.

An active convention committee is perfecting plans to assure that all who attend the meeting will have a pleasurable and profitable time.

James Duncan Died During Operation

JAMES DUNCAN, president of the Illinois Stoker Co., died unexpectedly on January 9, in New York City during an operation for gall stones. Mr. Duncan was born in Alton, Ill., in 1860, and, due to the death of his father, was forced to quit school in his youth and went to work as a laborer in the foundry of Brunner & Duncan, which he purchased 35 yr. ago.

Besides his interests in the Illinois Stoker Co., Mr. Duncan was president of the Illinois Co., a holding com-

pany having many interests including coal mines, had holdings in several railway companies, having last year bought the south end of the Chicago, Peoria & St. Louis, and was also an important holder of stock in St. Louis banks and trust companies as well as in many Illinois banks. Mr. Duncan is survived by three brothers, and two sisters.

F. F. Vater Killed in Auto Mishap

FRIENDS and acquaintances of Frank F. Vater were shocked to learn of his sudden death on January 10, due to an automobile accident near Milwaukee. Those in the power plant field will remember Mr. Vater as president of the Power Plant Specialty Co. of Chicago.

He was born at Indianapolis, December 24, 1859. In his earlier years in business he was connected with the Atlas Engine Works as a draftsman and salesman. Later on he was the head of a power plant equipment company in Minneapolis. Shortly after the World's Fair in Chicago he became connected with Westinghouse, Church, Kerr & Co., which firm represented the Westinghouse Electric and Mfg. Co. in securing contracts for power plant equipment. He was also associated for a short time with the Filer-Stowell Co. of Milwaukee and the A. Sorge, Jr., Co. of Chicago.

In 1904 he organized the Power Plant Specialty Co. of Chicago, of which he was the head when he died. This firm specializes in boiler feed water analysis and treatment.

He was a member of the American Society of Mechanical Engineers, the Western Society of Engineers and the Engineering Advertisers Association.

He is survived by his wife, Ella N. Vater, a son, Donald F. Vater, and a daughter, Mrs. Fred Schmitt of Milwaukee.

News Notes

GRISCOM-RUSSELL Co. has moved its main office to 285 Madison Ave., New York.

THE TERRY STEAM TURBINE Co. of Hartford, Conn., announces the appointment of John M. Rittelmeyer, with offices in the Healey Bldg., Atlanta, Ga., as representative in this territory.

PENNSYLVANIA CRUSHER Co. moved its general offices from the Stephen Girard Bldg. to the Liberty Trust Bldg. at the corner of Broad and Arch Sts., Philadelphia, Pa., on January 1, which will give the company additional space and adequate facilities for serving its customers.

THE BAKER ICE MACHINE Co. of Omaha, Nebr., has established a branch agency at 612 Race St., Philadelphia, where a complete line of its products will be carried for distribution to Eastern States. This new branch will be managed by H. G. Venemann, who for the past 9 yr. has been general sales manager at the factory in Omaha.

J. HENRY RORABACK has been elected president of the Connecticut Light & Power Co., succeeding Lewis Lillie of Philadelphia. Mr. Roraback has long been active in the affairs of the company, having been its counsel at the time its charter was obtained, and has been vice-president of the company since its incorporation in 1917.

THE NATIONAL VALVE and Manufacturing Co., Pittsburgh, Pa., announces the appointment of the Ernest E. Lee Co., 115 South Dearborn St., Chicago, Ill., as district representatives to cover the territory including the State of Illinois south to Springfield, Eastern Iowa, Southern Wisconsin and Northern Indiana.

ORDERS RECEIVED by the General Electric Co. for the year ending December 31, 1925, amounted to $302,513,380, according to an announcement by Gerard Swope, president of the company. Compared with $283,107,697 for the year 1924, this was an increase of 7 per cent. For the three months ending December 31, 1925, orders totaled $78,636,669, compared with $80,009,978 for the same quarter of 1924, a decrease of 2 per cent.

IN CONNECTION with an expansion program for 1926, the Detroit Edison Company, Detroit, Mich., is arranging for extensions in its power plants at Trenton Channel and Marysville. At the first noted, the work will include the installation of two 50,000-kw. turbo-generators, condensers and auxiliary machinery, while at the Marysville Station, a 30,000-kw. turbo-generating unit, and accessories will be installed. A contract for the prime movers has been given to the General Electric Co., and it is expected to place work in progress at an early date. The company has called a meeting of stockholders on Feb. 1, to approve an increase in capital from $85,000,000 to $122,000,000, a portion of the proceeds to be used in connection with the expansion program.

THE DRAKE NON-CLINKERING Furnace Block Co. of New York City, announces the following changes in its organization: Alfred Campbell, who was formerly district sales representative in the Pittsburgh and Cincinnati territories, has been appointed general manager. Harry Baumgartner, who was formerly with the Public Service Co. at Essex Station, has been retained as refractory engineer. D. B. Wilson has been appointed district sales representative in Philadelphia and is also in charge of Baltimore and Washington territories.

ROBERT SPURR WESTON and George A. Sampson, consulting engineers, were speakers before the January meeting of the New England Water Works Association on "Improvements of the Keene, N. H., Water Works," and Charles W. Sherman on "Economy of Municipal Bonds for Water Works Construction." The meeting was held at the Twentieth Century Club, Boston, Mass.

THE PAIGE & JONES CHEMICAL Co. has purchased property adjoining its plant at Hammond, Ind., and is constructing extensive additions that will double the plant capacity and will give combined office space of over 5000 sq. ft.

MANY IMPORTANT development plans have been inaugurated by the operating companies in the Midland Utilities Co. during the past few months. The biggest development planned is the construction of a large electric generating station at Michigan City, Ind., by the Calumet Gas and Electric Co. The initial capacity of this station will be 60,000 kw. It will be designed for the installation of additional and larger units as they are needed. Construction of this station will begin in the early spring and the first generating unit, which will consist of two turbines each with a capacity of 30,000 kw., is scheduled to be placed in operation in August, 1927.

A 10-STORY REFRIGERATING plant, storage warehouse and a center for various wholesale branches of meat-packing concerns, is to be erected at 106th Street and the Calumet River, Chicago, Illinois, by the South Chicago Cold Storage Company. Work on the building is expected to start in the spring of 1926, and plans will soon be drawn for the building by B. K. Gibson Co., 624 S. Michigan Ave., Chicago.